Indus River Basin

Common Concerns and the Roadmap to Resolution

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Centre for Dialogue and Reconciliation

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Shakil Ahmad Romshoo

Preface

Indus water, the lifeblood of the billions of people who live in the river basin shared between India (29%), Pakistan (63%), China and Afghanistan (8%), supports a multitude of ecosystem services essential to sustain economic growth, alleviate poverty, support prosperity, secure food supplies, fuel energy demand and above all it guarantees political stability to the region. Arising from the Tibetan Plateau in western China, the Indus River and its tributaries travel northwest through the Himalayan valleys, and after crossing into the Kashmir region and traversing Pakistan, flows out into the Arabian Sea. The mountainous Himalayan upper catchments host large reserves of water in the form of glacial ice and permanent snow and sustains one of the world's largest integrated irrigation networks down streams.

Occupying 92% of the basin, the Indus waters from five rivers are shared between two main stakeholders, namely India and Pakistan, through the Indus Water Treaty (IWT) signed in 1960. The treaty is often cited as a success story for transboundary sharing of river waters, as it has survived three wars, cold relations between India and Pakistan and the ill-will over the festering conflict on Kashmir. Over the last two decades divergent national views have emerged about the interpretations of different clauses of the Indus Water Treaty. Furthermore, some differences have cropped up recently over the hydropower projects planned by India in the Upper Indus Basin (UIB), and this has the potential to further spoil the relations between the two countries.

Many regions in the two countries are beginning to experience moderate to severe water shortages, brought on by the simultaneous effects of agricultural growth, industrialization, urbanization, population growth and climate change. With the increasing demand of water for irrigation, drinking water and industrial use, there is the likelihood that many regions in the downstream may become water scarce, thanks to the changing climate and rapid socio-economic and demographic changes. In the future, diminishing and degraded freshwater resources could lead to internal instability across the south Asian region. Besides the issues of water sharing, several water and energy related issues are critically affecting the food security, environment and agriculture in the basin. It is in this context that water security is emerging as an increasingly important and vital issue for both India and Pakistan.

The indicators of climate change are quite loud and clear in the Indus basin. The receding glaciers, scanty snowfall, the changing land system patterns, increasing demands for water to meet irrigation, industrial and domestic water demands, all are impacting the water availability in the basin. This is evident from the significant decline in stream flow as observed in most of the tributaries draining the Indus basin.

The lack of effective sharing of the hydrological information in a transparent and cooperative manner has led credence to wrong notions of and attributions to the declining stream flows in Pakistan. Again, the linking up of security concerns to the management and sharing of Indus waters has further complicated the water discourse over the sharing of Indus waters between the two countries. This is setting off a spiral of discontent and mistrust between the two countries. Therefore, there is urgent need to rebuild cooperation and trust over the water issues at various levels involving all the stakeholders from the two countries. It is heartening that there have been several initiatives under Track-II, involving stakeholders with diverse background from both the countries, to make the two countries to synergize their concerns on the sharing of Indus waters. Therefore, it is hoped that the cooperation that builds on existing frameworks over the sharing of Indus waters could not only present opportunities for better water management between those two countries, but may also offer pathways to confidence and peace building between the two countries to amicably settle political and other issues.

This report is the outcome of a series of deliberations on water issues between the countries, organized under the auspices of Centre for Dialogue and Reconciliation (CDR), New Delhi and Jinnah Institute, Pakistan. It was felt that there are more common interests than aversions between the two countries with regard to ensuring the sustainability of water resources in the Indus basin. The two countries, after all, share common concerns ailing the Indus water system. Out of all the concerns, explicitly and otherwise expressed by the stakeholder in the two countries, the main problems shared by a cross section of people in both counties include concerns about climate change

and its impacts on the cryosphere, dwindling water resources in the upstream part of the basin, increasing water needs of the growing population downstream, shrinking per capita water availability in both the countries, excessive pumping of groundwater resources and the dwindling groundwater levels, inefficient water usage, cumulative impacts of the cascade of proposed hydropower projects in the upper Indus basin, food security concerns and the increasing frequency of flooding and problems associated with this.

All these issues have been deliberated at length in various chapters of the report, highlighting the causes and consequences of water sustainability at different spatial and time scales. There was a consensus among the participants of these meetings that the two countries should agree to develop a time-bound robust strategy and a framework to address these common concerns through a modular basin wide approach that could help to generate the required information and knowledge for guiding policy for better and sustainable management of the dwindling water resources in the basin.

This report, comprising of four chapters, therefore makes an in-depth survey and analysis of various aspects of the Indus water system based on primary and secondary data sources. Chapter one discusses the emerging tensions on water use globally with special reference to the history and mechanism of Indus water sharing between India and Pakistan, and deliberates on perceived water concerns in the two countries, and finally identifies the interest groups linked to specific concerns. Chapter two describes the defined concerns between the two countries and specifically discusses observed historical changes in the waterflow in the Upper Indus Basin (UIB); demographic changes in the UIB basin and its impacts on water demand; the historical changes in the land use and land cover in the UIB and its impacts on the water resources (including irrigation); technical and managerial issues related to the sharing of trans-boundary Indus waters; and the depletion of groundwater resources in the Indus basin. Chapter three discusses the new, emerging and anticipated concerns over the sharing of Indus waters under the impact of climate change on the various water sources; the impact of proposed hydroelectric projects on water sources; and any other concerns about water by any of the stakeholders. Finally, the chapter four deliberates on the common concerns and presents a roadmap for resolution. This chapter specifically discusses the common concerns in both the countries (and in Kashmir); the proposed roadmap for addressing the common concerns; involvement of academia, government and non-governmental actors to address "common concerns" and informed diplomacy to deal with policy issues.

It is hoped that this report will be an important milestone for developing a cooperative framework between the two countries to address common concerns so that a mutually agreed upon vision for integrated and joint management of the water resources can be implemented in the basin for sustainable development of the waters shared between the two countries.

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Executive Summary

Vast areas across the length and breadth of the Indus basin shared between India and Pakistan are beginning to experience water shortages, compounded by the simultaneous effects of agricultural growth, industrialization, urbanization, population growth and climate change. The Indus Water Treaty (IWT), which governs the sharing of water between the two nations, is considered to be one of the most successful water sharing endeavours in the world today even though analysts acknowledge the need to update certain technical specifications and expand the scope of the document to include climate change. The IWT has survived despite three wars, several skirmishes and frequent military mobilizations by India and Pakistan. But some of the disputes that arose in the context of the treaty are also indicative of the nature of the treaty and the nationalist-driven hydro-politics of the Indus basin. In the future, diminishing and degraded freshwater resources could lead to internal instability in the region. Further some differences have cropped up between the countries recently over the hydropower projects planned by India in the Upper Indus Basin and have the potential to further spoil the relations between the two countries. It is in this context that water security is emerging as an increasingly important and vital issue for both India and Pakistan. All these issues have been deliberated at length in various chapters of the report highlighting their causes and consequences.

There is a need for persistent efforts at government and non-government level to bring all the stakeholders and interest groups on a common platform to facilitate a better understanding of each other's concerns and clearing the misgivings and ultimately building a consensus on how to address the emerging real issues related to the smooth implementation of the IWT. The best way to deal with the Indus water issues is to jointly look into the problems of entire Indus basin, which could materialize only if there is a political will on both the sides. The collaborative understanding of the system may, in due course of time, when the political relations between the two countries improve, finally lead to the joint management of the basin.

Conscious of their obligations to bridge the differences between the two countries on emerging water concerns, Centre for Dialogue and Reconciliation (CDR), New Delhi and Jinnah Institute, Pakistan jointly organized a series of deliberations on water issues confronting the two countries involving stakeholders from both the countries. It was decided during these dialogues that there is a need to document all the water concerns between the two countries using the existing knowledge on the subject. It was also decided that wherever required information on the new and emerging concerns shall be generated through firsthand analysis of the available data. It was a consensus among the participants of these meetings that the two countries should agree to develop a time-bound robust strategy and a framework to address these common concerns through a modular basin-wide approach that could help to generate the required information and knowledge for guiding the policy for better and sustainable management of the dwindling water resources in the basin.

This report, comprising four chapters, therefore makes an in-depth survey and analysis of various aspects of the Indus water system based on primary and secondary data sources. The first chapter discusses the water concerns in India and Pakistan as articulated by various interest groups and stakeholders. The material and discussion in this chapter is organized into the following specific topics:

a. Emerging tensions on water use globally

b. Water sharing history and mechanism between India and Pakistan

c. What are understood as 'water concerns' in the two countries?

d. Which interest groups have which concerns, and how are they defined?

Different interest groups in both the countries define the water concerns differently. In order to get access to the latest material on the topic, newspapers, newsletters, Internet and other current information sources have been accessed to provide a current and contemporary viewpoint of various stakeholders on the subject. The objective has been to document these concerns as objectively as possible and the author and sponsors do not necessarily subscribe to these concerns.

The second chapter discusses a number of well-defined concerns, based on scientific observations, knowledge and informed data analysis, that affect the usage and distribution of water resources between India and Pakistan. The material and discussion in this chapter has been organized into the following specific topics:

a. Observed historical changes in the water flows in the Upper Indus Basin (UIB)

b. Demographic changes in the UIB and their impacts on water demand

c. The historical changes in the land use and land cover in the UIB and its impacts on the water resources (including irrigation)

d. Technical and managerial issues related to the sharing of trans-boundary Indus water

e. Depletion of groundwater resources in the Indus basin

Conclusions about each of the above concerns are based on the scientific analysis of the available data from various sources in the Jhelum basin. The stream flows are showing statistically significant decline in most of the watershed in the Jhelum basin due to the shrinking cryosphere and other hydrological changes in the basin. Due to the tremendous socio-economic transformation in the Jhelum basin, the demands for water for drinking and other domestic purposes has increased significantly. Concurrently, several changes in the land cover have been observed in the Jhelum basin that have impacts on the usage of available water. The causes and consequences of the depleting groundwater resources in the entire Indus basin are also discussed threadbare in this chapter in light of the secondary information available in the two countries.

The third chapter discusses the new and emerging concerns on water sharing between the two countries. The material and discussion in this chapter have been organized into the following specific topics:

a. Impacts of climate change on various water sources

b. Impacts of proposed hydroelectric projects on water sources

c. Any other concerns about water by any of the stakeholders

Under each of these topics, we have briefly discussed the international scenarios and tried to link that with the available literature and indices on the UIB. For example, for climate change, there is a plethora of information available on the impacts of climate change on the water resources at the global level. We have showcased how the climate change is impacting the cryosphere, stream flows, food security and other sectors in both the UIB and the Lower Indus Basin (LIB). Similarly, we have briefly discussed the impacts of the proposed cascade hydropower projects on the availability of water resources in the long run and on different aspects of the environment, mostly taken from the case studies conducted elsewhere. Some of the emerging and futuristic concerns on the availability and use of water resources in the basin, as expressed by various stakeholders in the basin, are also discussed in this chapter.

The fourth chapter discusses the common concerns, expressed explicitly or otherwise, in the two countries about the use of Indus water. In order to address these common concerns, a joint multi-partner initiative, involving the stakeholders from the two countries and beyond, is proposed that shall lead to the formulation of a roadmap for sustainable management of the Indus water system. The material and discussion in this chapter has been organized into the following specific topics:

a. Common concerns in both the countries (and in Kashmir)

b. Proposed roadmap for addressing the common concerns

c. Involvement of academia, government and non-governmental actors to address 'common concerns'

d. Informed diplomacy to deal with policy issues

We discuss here the seven common concerns on Indus water and what needs to be done, in a cooperative framework, to generate a body of information and knowledge about these concerns so that a robust strategy is put in place basin-wide to address these concerns for the sustainable use of the depleting water resources in the basin. The roadmap for developing the robust strategies to address these concerns at the basin scale envisages cooperation and sharing of expertise and resources among various stakeholders. These stakeholders will come from academia, governmental organizations, NGOs and other segments of the society and shall work under a consortium for generating the required knowledge for developing action plan for addressing the common concerns on the Indus water system. The setting up of the consortium with constitution from various academic, government and non-governmental organizations of the two countries would itself tantamount to a major step towards finding amicable solutions to the common and emerging concerns on the sharing of the depleting Indus

water between the two countries. It is hoped that the proposed initiative shall not only provide the knowledge and mechanism to address these concerns but inter alia build and strengthen the trust between the policy and decision makers of the two countries and encourage them to address other festering bilateral problems confronting the two countries. It is also hoped that the repository of knowledge to be jointly generated through the consortium under the initiative shall provide the informed confidence to the policy and decision makers of the two countries to approve the action plans for addressing these common concerns, even if it requires supplementing the existing IWT. We strongly believe that the putting in place and strengthening the consortium should be the first priority under the initiative and would hopefully lead to the joint Indus basin management of the water resources between the two countries in the foreseeable future.

CHAPTER I

Definition of Water concerns in India and Pakistan

Summary: *This chapter discusses the water concerns in India and Pakistan as articulated by various interest groups and stakeholders. We have organized the material and discussion in this chapter into the following specific topics:-*

a) Emerging tensions on water use globally

b) Water sharing history and mechanism between India and Pakistan

c) What are understood as 'water concerns' in the two countries?

d) Which interest groups have which concerns, and how are they defined?

The Indus Water Treaty, that governs the sharing of water between the two nations, is considered to be one of the most successful water sharing endeavours in the world today, even though analysts acknowledge the need to update certain technical specifications and expand the scope of the document to include climate change. The IWT has survived despite two-and-a-half wars and frequent military mobilizations by India and Pakistan. But some of the disputes that arose in the context of the treaty are also indicative of the nature of the treaty and the nationalist-driven hydro-politics of the Indus basin.

Different interest groups in both the countries define the water concerns differently. In order to get access to the latest material on the topic, newspapers, newsletters, Internet and other current information sources have been accessed to provide a current and contemporary viewpoint of various stakeholders on the subject. The objective has been to document these concerns as objectively as possible, and we don't necessarily subscribe to these concerns.

There is a need for persistent efforts at the government and non-governmental level to bring all the stakeholders and interest groups on a common platform to facilitate a better understanding of each other's concerns, clear the misgivings and ultimately build a consensus on how to address the emerging real issues related to the smooth implementation of the Indus Water Treaty (IWT).

1.1 Emerging tensions on water use globally

Water is a diminishing resource the world over. It is increasingly becoming a scarce commodity with competitive uses having their independent socio-economic consequences. Despite water scarcity being a serious issue in many countries around the world it has often been overlooked, underfunded and undervalued within foreign policies of nations around the world. A government's ability to provide and manage access to water is critical for ensuring political, economic and social stability of a nation (USA, 2011). The need of the hour is the conservation and judicious use of this water resource. Though efficient use and effective conservation of water resources are required in various water systems, attaining such goals is difficult in trans-boundary river systems because this requires cooperation among riparian countries which is not often the case. As a result, many countries are unable to utilize their shared water resources owing to riparian conflicts (Kirmani and Le Moigne, 1997).

In the current world scenario, we are witnessing water-related conflicts and crises. Water, when it is a shared resource and that too between traditional adversaries, rather than dousing tensions becomes a volatile agent (Salam, 2010).This is the case in several nations of South Asia where water sharing and shortage is triggering concerns and fresh water crisis is brewing up with great intensity, with water already being an extremely contentious and volatile issue in this region. One-third of the world population is suffering from a shortage of water,

raising the prospect of water crisis in countries such as China, India and Pakistan (Shiva, 2002).The supply of fresh water in many countries is already at a critical point - particularly in China, India and Pakistan, home to over half of the world population. Due to the massive population, national resource requirements and ineffective resource-sharing policies, the potential for water wars involving these three countries is significant (Elizabeth, 2004). The potential for water conflict is greatest in developing countries that lack effective tools for the proper management of this resource (Bajpaee, 2006). With the growing population, industrial, agricultural and domestic uses, climate change and glacier melting resulting in overall environmental degradation, the rivers are becoming a bone of contention between countries and communities within and outside the nation boarders (Khalid, 2008; Yagi, 2011).

If the first decade of the new millennium was shaped by terrorism, the next two decades (2010-2030) will witness issues around water dominating internal and external policies of countries, especially in South Asia (John, 2011). Asia has increasingly faced a steady reduction in fresh water availability. Increasing water shortage has made South Asia a water-stressed region (Bajpaee, 2006).There are more people in the region than ever before and their dependence on water for various needs continues to multiply by leaps and bounds. The quantum of water available, for the present as well as future has reduced dramatically, particularly in the last half of century. Generally, this is attributed to water and fertilizer intensive farming, over exploitation of groundwater for drinking, industrial and agricultural purposes, changing climate and its impacts on water resources, large-scale contamination of water sources, total inertia in controlling and channelizing waste water, an indifferent approach to water conservation programmes and populist policies on water consumption (John, 2011). The question of utilization of water for hydropower generation and commercial irrigation is a matter of great concern responsible for emerging concerns and tensions in the region.

1.2 Water sharing history and mechanism between India and Pakistan

In Central and South Asia, particularly Afghanistan, Pakistan and India, the impact of water scarcity is fueling dangerous tensions that will have repercussions for regional stability. The national security implications of this looming water shortage directly caused or aggravated by agriculture demands, hydroelectric power generation and.climate instability - will be felt all over the world. The four main co-riparian states of this region are India-Pakistan and India–Bangladesh-Nepal lying in west and east respectively. Although fresh water scarcity is a common problem across the borders of these states in this region, the situation is particularly acute in Pakistan and India.

An interstate conflict over water could have exceptionally grave consequences for regional security and stability. The continued depletion of water resources and the lack of significant action to rectify the shortages is being highlighted as a major cause that could lead the major powers in Asia - China, India and Pakistan in particular - to wage a full-scale war over these resources (Bajpaee, 2006; Shiva, 2002).

Furthermore, the severity of this problem is highlighted by the statement: "Such abstract arguments miss the most crucial point - when water disappears, there is no alternative. For Third World women, water scarcity means travelling longer distances in search of water. For peasants, it means starvation and destitution as drought wipes out their crops. For children, it means dehydration and death. There is simply no substitute for this precious liquid, necessary for the biological survival of animals and plants" (Shiva, 2002). Water conflicts of various sorts are happening all over the arid parts of the world. As more and more water is collected behind dams, and otherwise controlled, it is the powerful that get access to the water and the weak that lose. So there is a serious global issue about water governance as well (Bajpaee, 2006; Comstock, 2007).

Both India and Pakistan have a high rate of population growth, widespread poverty, declining food production and a rapidly rising demand of water for domestic, agricultural as well as industrial uses. The freshwater crisis is reaching critical proportions in these two countries at an alarming speed. These two signatories of the IWT, face increasing water scarcity problems, mainly due to high inefficiency of water use in irrigation (80% of the water is used for low value agriculture production), increased levels of water pollution and competing needs driven by high population growth (Briscoe and Malik, 2006; World Bank, 2005).

Accordingly to international law, there are two conflicting principles pertaining to the sharing of international waters. India claimed 24 per cent of the rivers' flow, based on the "principle of equitable utilization," while Pakistan argued that India should get 12 per cent of the flows, based on the "principle of no appreciable harm". Briscoe (2005) opines that water is emerging as a core issue between India and Pakistan for two reasons. First, the water issue is closely related to the unresolved issue of Kashmir and thus is difficult to separate from concerns of security. Second, Pakistan is constructed around a single river basin, on which its economy, agriculture and energy depend. Almost all of the water in Pakistan is fully

allocated and used, and comes from neighbouring countries (primarily India, but also China and Afghanistan).

Within the parameters of the treaty, India could develop its hydropower without impacting Pakistan's water use. This could even be a benefit for Pakistan if India took into account Pakistan's interests in operating its hydropower plants. If relations between India and Pakistan were normal there would be very few problems. But in the context of tense relations between the two countries, the already complex water issue has been both exacerbated by, and used to inflame public opinion. Both India and Pakistan have good reason to modernize the implementation of the treaty, with the ball mostly in India's court. Modernizing the treaty's dispute-resolution mechanism would not only take this explosive issue off the table, but it would be an important step in building more stable and peaceful relations between the two countries (Briscoe, 2005).

After the creation of Pakistan in 1947, disagreements began to arise over sharing of river waters, leading to the 1960 Indus Water Treaty, an attempt at a resolution brokered by the World Bank. The importance of the partition's impact on the waters of the Indus River has almost invariably been highlighted. This could hardly have been otherwise given the immense importance of the waters of six rivers of the Indus system (Indus, Jhelum, Chenab, Ravi, Beas, Sutlej) to the irrigation-dependent agriculture of both India and Pakistan (Wirsing, 2008). The key components of the Indus Water treaty demonstrated that India and Pakistan could work together if the payoff was large enough. The first key part of the treaty involves the division of the Indus River system. This system consists of three eastern rivers - the Sutlej, the Beas and the Ravi, and three western rivers - the Indus, the Jhelum and the Chenab. The treaty gave India exclusive rights to the three eastern rivers up to the point where they enter Pakistan. At the same time, Pakistan was given exclusive rights to the western rivers (Indus Waters Treaty, 1960). The second key aspect was the creation of the Indus Commission. This commission was created to adjudicate future disputes over the allocation of water and required annual meetings to discuss any potential problems (Indus Waters Treaty, 1960-Article-VIII).

Though the treaty is perhaps the most enduring pact between the two nuclear powers, it is coming under increasing strain (Haq and Khan, 2010). Despite the treaty's success over the past decades, India and Pakistan have experienced numerous disputes over modifications to the rivers - some of which remain unsettled. The Indus Waters Treaty is widely and correctly considered to be the most important water treaty in the world, and has endured despite 50 years of hostility between India and Pakistan. However, in recent years, India's growing portfolio of hydroelectric plants on the Indus, Chenab and Jhelum in Indian-held Kashmir, have put the treaty under unprecedented stress (Briscoe, 2005). The increasing need to maintain a steady flow of water for survival and the recent rise in disagreements over aspects of the treaty raise the question of whether the treaty is still adequate. While one might triumphantly hail the IWT as a successful bilateral approach to resource sharing and admire the mechanism for resolving problems through 'commitment to negotiations' and 'arranging the negotiations', one cannot ignore the reality of the Indus waters being under stress both in qualitative and quantitative terms. The questions that are now being raised are: has the treaty, under changed hydrological circumstances, outlived its utility? Does it need to be renegotiated, possibly even negotiated afresh? (Sinha,2008). The treaty is considered to be one of the most successful water-sharing endeavors in the world today even though analysts acknowledge the need to update certain technical specifications and expand the scope of the document to include climate change (Bakshi and Trivedi, 2011). The IWT has been relatively successful, at the very least by virtue of surviving two-and-a-half wars and frequent military mobilizations by India and Pakistan. But some of the disputes that arose in the context of the treaty are also indicative of the nature of the treaty and the nationalist-driven hydro-politics of the Indus basin (Mustafa, 2010).

The 1960 Indus Water Treaty is internationally regarded as a successful instance of conflict resolution between two countries that have otherwise been locked in conflict. However, the expression of satisfaction at the fact that the arbitration provisions of the Treaty have not so far been invoked, seems to have changed in recent years. There are some who question the statement that the treaty is a good example of conflict resolution; they feel that the surgery that it did on the river-system was harmful. There is also a body of opinion in both countries that the division of waters under the treaty was unfair, but the unfairness alleged in one country is the exact opposite of that alleged in the other (Iyer, 2010a).

The international organizations are expected to serve as a mechanism to mitigate conflicts among riparian countries in an international water body with a view to more rational management of that same water system. However, international organizations have so far had very limited success in acting in such a role (Nakayama, 1997). For example, though the Indus Water Treaty adopted in 1960 by India and Pakistan has been regarded as the 'success story' of the World Bank, it has made few direct interventions in international water affairs in the last 36 years (Kirmani

and Rangeley, 1994). As the treaty was designed in 1960 and water availability, demand and supply mechanism have changed considerably since then, the question is less about the IWT's durability and more about its adaptability (Bakshi and Trivedi, 2011).

Despite the looming threat of water scarcity staring at many of the countries in South Asia, there has been a persistent reticence, often deliberate, in working together to reduce the impact of the impending crisis on the people of the region. Most of the blame should squarely lie on the political and bureaucratic leadership of these countries, which has treated water strictly as a sovereign and political issue, ignoring the fact that many of the rivers and river systems that feed billions in the region transcend political boundaries (John, 2011).

India and Pakistan need to take substantive measures within the scope of the treaty and outside it, through mutual agreement, so as to remove mutual distrust and address operational difficulties in terms of effective functioning and interpretation of the treaty, recognizing and responding to changes in the shared river system. India should appreciate Pakistan's dependence and vulnerabilities on the Western rivers and should go for smaller hydel projects on these rivers that are more eco-friendly and address Pakistan's legitimate fears about India's control to manipulate the flow of these rivers. Further, sources of growing water stress in the two countries should be addressed through efficient water management in each country (Akhtar, 2010). He further suggested that some of the steps required include timely data sharing through installation of telemetry system; transparency in data sharing regarding the construction of new Indian projects; joint watershed management and joint commissioning of environmental studies; cooperation in ensuring quality of water bodies; strengthening the functioning of the Indus Waters Commission by expanding its scope and mandate and internal management of water resources, plus sharing best practices in efficient utilization of water.

1.3 What are understood as 'water concerns' in the two countries?

a. Pakistani Concerns on Water Sharing

The mighty Indus river system is the largest water source in Pakistan, supplying about two-thirds of water for irrigation and domestic uses. Water use pattern in Pakistan is 95% for the agriculture sector, 3% for drinking and sanitation sectors, besides 2% for the industry (Sinha, 2008). Over the past decade or so, changes in climate and the accelerated pace of the earth's warming have moved the issue of climate change to the top of the agenda in this region. Pakistan is one of the world's most arid countries in which average rainfall is less than 240 mm a year. The country's water resources consist mainly of rainfall, rivers, glaciers and ground water.

According to the UN Social Commission for Asia and the Pacific (UNESCP, 2011) Pakistan is about to become a 'water scarce' country as it has limited water resources. Pakistan is highly dependent on water resources originating in the mountain sources of the upper Indus for irrigated agriculture, which is the mainstay of its economy. Hence any change in available resources through climate change or socio-economic factors could have a serious impact on food security and the environment in Pakistan. In terms of both ratio of withdrawals to runoff and per-capita water availability, Pakistan's water resources are already highly stressed and will become increasingly so with projected population changes. Potential changes to supply through declining reservoir storage, the impact of water logging and salinity or over-abstraction of groundwater or reallocations for environmental remediation of the Indus Delta or to meet domestic demands, will reduce water availability for irrigation (Archer et al., 2010). On the above account, water is becoming increasingly a scarce commodity in Pakistan.

The division of river system across the geographical boundaries of India and Pakistan was a physically asymmetric hydrological divide (Michel 1967, Daene C. McKinney 2011, Margalla papers 2011, IUCN 2011). The boundary between India and Pakistan was drawn on religious grounds, paying no attention to hydrology. As a result, more than 85 per cent of the irrigated area of the Punjab - the breadbasket of the subcontinent - was included in Pakistan, while the headwaters of the Punjab rivers were in what subsequently became Indian-held Kashmir (Briscoe, 2005). The partition of India did not consider the implications of dividing the Indus basin, although Sir Cyril Radcliffe did express his hope that, some joint control and management of the irrigation system may be found" (Mehta 1986). He opined that whole network was so interconnected that the only proposal he could make about the water resources was to operate the Punjab Irrigation System as a joint venture. This suggestion was repeated by Mr. David Lilienthal in 1951, former chairman of the Tennessee Valley Authority. But the proposal was never formulated and the idea was rejected first by India and then by Pakistan. The inappropriate approach of the Boundary Commission is reflected in the most crucial division of the Sutlej works, where it was decided that the district boundaries, and not the actual course of the Sutlej River, should constitute the boundary between the east and west Punjab (Gazette of India Extraordinary, 1947).

The partition of the Indian subcontinent in 1947 gave birth to a long history of conflict between India and Pakistan. The source of this instability primarily revolves around several issues. Of these, the Kashmir region remains the most contentious. Despite decades of multilateral and bilateral talks over Kashmir, the issue remains contentious, unresolved and the primary source of water resource tension between India and Pakistan (Pakistan Tribune, 2007). The rivers flowing from the Kashmir region into Pakistan are the life-blood of this agriculture-based country. Soon after the partition, India did not take time to assert her upstream privilege on water control. The canals diversions from the Ravi and Sutlej were stopped in 1948, a few months after the partition. It led to trans-boundary water negotiation, while leaving a clear message of the upstream power (A. T. Wolf. 1999, Margalla paper 2011). As the monsoon flows receded in the autumn of 1947, the chief engineers of Pakistan and India met and agreed to a "Standstill Agreement," which froze water allocations at two points on the river until 31 March 1948, allowing discharges from head works in India to continue to flow into Pakistan. On 1 April 1948, the day that the "Standstill Agreement" expired, in the absence of a new agreement, the provincial government of East Punjab (India) discontinued the delivery of water to the Dipalpur Canal and the main branches of the Upper Bari Daab Canal (Patric Doyle. et, al 2007, Michel 1967).

At an Inter-dominion conference held in Delhi on 3–4 May 1948, India agreed to the resumption of flow, but maintained that Pakistan could not claim any share of those waters as a matter of right (Cas Patric Doyle. et, al 2007). Pakistan contested India's position, which was aggravated by the Indian claim that since Pakistan had agreed to pay for water under the Standstill Agreement of 1947, Pakistan had therefore recognized India's water rights. Pakistan countered that they had the rights of prior appropriation, and that payments to India were only to cover operation and maintenance costs (Gulhati, 1973; Salman and Uprety, 2002; Alam, 1998). While these conflicting claims were not resolved, an agreement was signed, later referred to as the Delhi Agreement, in which India assured Pakistan that it will not withdraw water without allowing time for Pakistan to develop alternate sources.

Pakistan later expressed its displeasure with the agreement in a note dated 16 June 1949, calling for the "equitable apportionment of all common waters," and suggesting the case be turned over to the World Court of Justice (Patric Doyle. et, al 2007). India rather preferred that a commission of judges from each side attempt to resolve their differences before turning the problem over to a third party. The stalemate continued through 1950 (Gulhati, 1973) (Aaron T. Wolf 2009 Patric Doyle. et, al 2007)

Since India cut off the Indus flow in 1948, a suspicion breeds in the minds of the Pakistanis that India may repeat the tactic in the event of any hostility between the two nations. It is likely that another attempt to stem the flow of the Indus River by either country (read India) would result in conflict - and possibly a nuclear one (Transboundary Freshwater Dispute Database). Concern is growing in Pakistan that India is pursuing policies in an attempt to strangulate Pakistan by exercising control over the water flow of Pakistan's rivers. The concern is most related to Pakistan's agricultural sector, which would be greatly affected by the building of dams and by the external control of the waters of several rivers that flow into Pakistan. The issue has a layered complexity, as three of the rivers flow into Pakistan through the Indian portion of Jammu and Kashmir, the territory over which the two countries have waged multiple wars (Haq and Khan, 2010).

Several experts believe that the IWT is not based on any clear principle of international or customary law when it divided the rivers on territorial consideration. No livelihood water securities were provided to the communities evolved along the rivers, no ecological and environmental allocations were made and no mechanism was proposed for the protection of river catchments and existing water bodies (IUCN 2010, Margalla Papers 2011). The principles put by both countries were conflicting; India invoked the principle of "equitable utilization" (without considering the prior uses, allocations and demands), while Pakistan stressed on the pre-partition practice of "priority to the existing uses and agreed allocations" and "no appreciable harm" downstream (Margalla Papers 2011). In the absence of any consensus on principles of international water law, the treaty was a political compromise around the narrow engineering solutions (Margalla Papers 2011). The division of rivers under the treaty was considered a key reason for the success of Indus Water Treaty but at the same time in Pakistan, it is considered a major act of its compromise and surrender on the Eastern rivers.

After the complete loss of the Eastern Rivers Pakistan's sovereign rights on the western rivers face many challenges (Margalla papers 2011). Many in Pakistan argue that the territories that went to India under partition were historically using less than 10 per cent of the Indus waters, and that the treaty was generous to India in giving it 20 per cent of the waters (Iyer, 2010a).There is abundant testimony that Pakistan's leaders at that time were fully conscious of their country's vulnerability on this count - and of its far-reaching security implications (Wirsing, 2008). The Indian control of water resources and water infrastructure upstream and the eventual diversion of their waters through canals, in absence of any treaty, would have meant Pakistan's quick economic

death. This economic threat was highly important in the minds of the Pakistani leaders (Korbel, 1966).The treaty solution was, in fact, very close to the Indian position held from the outset. Pakistanis contend that pending the settlement of the Kashmir dispute, India actually had no riparian claim on the western rivers to begin with. They argue that the contest should have been over rival riparian claims on the three eastern rivers that traversed both India and Pakistan. The IWT, by awarding all of the eastern rivers to India, was hardly a model of just arbitration between riparian parties (Haris Gazdar 2005).

Taking advantage of its geographic location, India has aptly tried to gain control of the western rivers that belong to Pakistan, hence depriving Pakistan of its due share and that may transform the whole country into a desert land (Hayat, 2010). The successive Pakistan government's perspective, regarding IWT is that, India's right to non-consumptive uses on the western rivers, —presents it with the endlessly frustrating and ultimately futile task of guarding its water resources against Indian poaching (Wirsing and Jasparro, 2006, Hayat 2010).

Critical to understanding the basis of the dispute and tussle over the sharing of Indus water, from the Pakistani perspective, is the sustainability of irrigated agriculture in the lower Indus basin. With a semi-arid climate, agriculture in the Indus basin is heavily dependent upon irrigation (Ahmad, 1964). This is reinforced by the large seasonal and annual variability in water availability, which is masked by large average annual runoff, 150-200 km3. For example, the Indus River measured at Kalabagh can change from 70 km3 during the summer to 12 km3 during the winter (Michel 1967; Gulhati 1973; Johnson 1979; FAO 1997). Therefore, Pakistan's geography makes it completely dependent upon the Indus basin for its agricultural, industrial and municipal uses (Mustafa 2001), the annual influx of water into the Indus river system through India being about 180 billion cubic metres (Briscoe and Qamar, 2005).

Unlike India, which has a number of river systems including the Ganges-Yamuna system in the north, or the Cauvery River in the south, Pakistan has waters from the Indus basin only. The agriculture sector not only meets the food demand of the growing population but also provides the raw materials for the industrial sector, notably cotton for the textile industry. The sector employs around 45% of the total labour force of the country whilst the 67% of the population living in rural areas is linked directly or indirectly to agriculture for their livelihoods. Textiles comprise 64% and food products 11% of total Pakistani exports; both are wholly dependent on agriculture. The linkage between water resources, through irrigation demand, to the economic wellbeing of the country is thus established (Archer et al., 2010).If Pakistan was deprived of her canal water from the Indus System, the whole of West Pakistan would really become a desert (Iliff, 1961).

Pakistani columnists, religious leaders and policy makers are increasingly articulating their concern over the water dispute in terms of a traditional rivalry against India and in terms of anti-Israel sentiment that has been fostered by the country's establishment over the years. In one such recent case, Ayaz Amir, a renowned Pakistani columnist, warned: "Insisting on our water rights with regard to India must be one of the cornerstones of our foreign policy. The disputes of the future will be about water" (The News, 2009). The dominant perception in the mass media in Pakistan also shares the view that its rights to western rivers are undermined by Indian violations of IWT. Majid Nizami, chief editor of a group of newspapers, observed that the water dispute with India could trigger a war. "Pakistan can become a desert within the next 10 to 15 years. We should show upright posture or otherwise prepare for a nuclear war" (Bokhari, 2010). The dispute over water is the third most important issue after terrorism and Kashmir that has been highlighted by Pakistani dailies like Dawn and The Nation (Khan and Shakir, 2011). Hamid Gul, former chief of Pakistan's Inter-Services Intelligence (ISI), charged: "India has stopped our water." (Tufail, 2009) Pakistan's Indus Basin Water Council (IBWC), a pressure group that appears deceivingly authoritative as an organization whose central purpose is to address Pakistani water concerns, currently maintains hegemony over the public debate of the issue. IBWC Chairman Zahoorul Hassan Dahir claimed that, "India, working in conjunction with the Jewish lobby" is using most of the river waters, causing a shortage of food, water and electricity in Pakistan (Tufail, 2009).

The steadily declining availability of water from the Indus has led various actors in Pakistan to raise 'water' as an important issue in the political arena and there have been efforts to mobilize popular support around such issues (Sinha, 2008). Syed Salahuddin, Chairman of the United Jihad Council, an umbrella organization responsible for coordinating the activities of all jihadi groups in Pakistan, was quoted as saying, 'Kashmir is the source where from all of Pakistan's water resources originate. If Pakistan loses its battle against India, it will become a desert (Strategic Foresight, 2005).' Another statement by Sardar Mohamad Anwar Khan, President of Kashmir under Pakistani Control, runs on similar lines: 'Pakistanis who believe that they can survive without Kashmir are wrong. The Pakistani economy is dependent on agriculture and hence on water, and therefore on Kashmir (Sinha, 2008).' Pakistani extremists have several times staged

protests along the India-Pakistan border, rallying against what they called India's unfair use of the shared waters of the Indus River. Former Prime Minister Sardar Sikandar Hayat has often reiterated the point: 'The freedom fighters of Kashmir are in reality fighting for Pakistan's water security and have prevented India from constructing a dam on the Wullar Barrage' (Waslekar, 2005).

The Pakistani military also considers the Indus and its lower riparian status as a weak point vis-a-vis India. Voices from various constituencies indicate that the issue of Kashmir and the distribution of the Indus waters are interdependent and inseparable and that any future solution will have to consider the equitable distribution of the river waters. In spite of its lower riparian apprehensions, Pakistan has long regarded the 'Indus water' as secondary to Kashmir but now, with changing times and growing needs, water dependency has increased. The water discourse is now intensely politicized. By linking the Indus to Kashmir (the IWT categorically forbids this), the 'lifeline' debate has been revived (Sinha, 2008). For Pakistan, it is now being proclaimed, Kashmir is water and water is Kashmir. It is not Kashmir as such but Kashmir's water that lies at the heart of the India-Pakistan hostility in general (Baid, 2008).

Some of the concerns of Pakistan regarding the IWT revolve around lack of prompt data sharing and transparency about the ongoing and planned Indian hydropower projects as provision of such information is essential for Pakistan to ensure that run-of-river plants are being operated according to the treaty (Khalid, 2008). Pakistan has often raised its doubts over India's run-of-the-river hydro-projects on the Chenab and Jhelum. In its riparian relations with India, a passionate debate was sparked by an array of ongoing and pipeline Indian projects including the Wullar Barrage, Baglihar and Kishenganga dams on the rivers allocated to Pakistan. The growing water scarcity, Pakistan's heavy dependence on supply of fresh waters from the western rivers, vulnerability to increasing number of Indian projects and apprehensions as lower riparian underlie the heated water discourse in the country that cuts across political parties/leaders, officials, farmer groups, media and public at large (Akhtar, 2010). There seems to be no solution to the conflict over the construction of new dams by India because India is not adhering to the provisions of the IWT in totality (Anees, 2009, Tufail, 2009). Pakistan is also apprehensive that development of hydropower infrastructure upstreams will give India a measure of control over rivers allocated to Pakistan, enabling India either to reduce water-flows to Pakistan or to release stored waters and cause floods (*Iyer, 2010b*). Regarding the Baglihar hydropower project, Pakistan raised six objections to the design of the dam and argued that the project was not in conformity with the IWT. These objections were related to pondage level, gated spillways, under-sluices, level of intake tunnels, height of gates and elevation of tunnels. Pakistan's objections primarily related to the design of the plant without questioning India's right under the treaty to construct hydroelectric dams and the feared that the dam will cause a loss of 6,000 to 7,000cusecs of water every day, equal to a 27 per cent decrease in the Chenab River (Kiani, 2004). So, Pakistan sought modification on free board, level of power intakes, pondage and spillway (Akhtar, 2010). Several experts (Hussain, 2010) and Pakistani media (*Dawn, 2005, Dawn, 2010*) exaggerately argue that the Baghlihar dam will have major security and economic implications for Pakistan owing to increased Indian control over its share of water supplies. In an editorial published on 27 June 2009, Pakistan's mass-circulation Urdu-language newspaper *Roznama Jang* said, "India is nursing an impious dream of turning the entirety of Pakistan into à desert." However, the neutral experts opinion on Baghliar has disappointed most of the Pakistan and was taken with a pinch of salt as it was not as per their expectations.

The discussion of water easily ignites popular passion because Pakistanis increasingly are confronted by an impending water crisis. In early 2009, it was estimated that Pakistan is on the brink of a water disaster, as the availability of water in Pakistan has been declining over the past few decades, from 5,000 cubic metres per capita 60 years ago to 1,200 cubic metres per capita in 2009. By 2025, the availability of water is estimated to fall to about 700 cubic metres per capita (Pakistan Strategic Country Environmental Assessment Report, 2006). M. Yusuf Sarwar, a member of the Indus Basin Water Council, has warned that the lessening flow of water in rivers and shortage of water generally could cause Pakistan to be declared a disaster-affected nation by 2013 (*Lubna, 2010*). Less than 20 per cent of below-surface water in the Sindh province, previously thought to be viable water source, is acceptable for drinking (*Tufail, 2009*). Amidst this shortage of water, Pakistan is also confronted with a number of internal factors that aggregate the problem. One columnist warned that with Pakistan's population set to jump to 250 million in just a few years time, a shortage of water, along with that of oil, sugar and wheat will become a major problem (*Tufail, 2009*). He wrote that Pakistan is also estimated to be losing 13 million cusecs [approximately 368,119 cubic metres/second] of water every year from its rivers into the sea, as it does not have enough reservoirs or dams to store water. Further tensions arise from allegations of inequitable distribution of water between various Pakistani provinces. The Indus River System Authority (IRSA), which allocates water to provinces, averted a major political controversy between

provinces in June 2009 by declaring that there would be no cuts in their water supply (*Daily Times, 2009*).

b. Indian Concerns on Water Sharing

The fact that water may emerge as a potential flash-point in the future is a concern that has been doing the rounds in India for many years now. India has long standing water disputes in South Asia with her neighbors on distribution of water resources, particularly rivers (Khalid, 2008). It has, for instance, had a long history of water woes - from the quibbling over Cauvery between Tamil Nadu and Karnataka to the sharing of Indus and Ganga waters with Pakistan and Bangladesh respectively. These disputes are increasing in intensity gradually, as the demand for fresh water increases. Although there have been no wars fought over water yet, the issue of sharing has often caused heartburn. There is the possibility that if present demographic, economic and environmental challenges increase, then this tension may lead to a crisis-like situation and probably wars between India and its neighbours would threaten regional stability (Khalid, 2008).

India is in a much better position than Pakistan because of her geographical proximity to Tibet, Kashmir, Himalayas' water resources, and the Bay of Bengal, which make it practically upper riparian in the Indus, Ganges-Brahmaputra and Meghna basins, all forming part of the main Himalayan river systems. Besides, India has the Deccan rivers - the Godavari, the Krishna, the Cauvery, and the Mahanadi; coastal rivers and rivers of the inland drainage basin. However, the demand for water continues outstripping the supply. India's overall per capita water availability has also declined from over 5,000 cubic metres in 1950 to 1,800 cubic metre in 2005. It may reach the threshold level of 1,000 cubic metre per capita in 2025 (Waslekar, 2005).The dominant perception in India is that "the growth of population, pace of urbanization and economic development will accentuate the pressure of increasing demand on a finite resource, and that the answer lies in large supply-side projects and long-distance water transfers" (Iyer, 2010a).

The basic driver for hydropower generation is growing electricity needs in India. The push for hydropower in India mainly comes from the need to meet the power demands of the 9% plus annual growth rate. Overall for the country, peak power demand in the year 2007-08 was 108,886 MW, while the peak power demand met was 90,793 MW; there was a shortfall of 18,093 MW or 16.6% of peak demand. Although there is a strong push for large hydro projects in India, the fact is that 89 per cent of its large projects generate power below the designed capacity (SANDRP Report, 2010). Therefore, harnessing the untapped hydropower potential of the Himalayan river systems is seen as a viable and climate-friendly alternative by the political and decision-making set up in India.

The 1960 Indus Waters Treaty between India and Pakistan raised the ire of many within India for its policy makers agreeing to indefinitely reserve four-fifths of the total waters of the Indus system for Pakistan. Many in India feel that the allocation of 80 per cent of the waters to Pakistan and 20 per cent to India was an unfair settlement foolishly accepted by the Indian negotiators (Iyer, 2010 a; Haq and Khan, 2010). The Indian media and officials always argue that India is not violating the IWT and only utilizing the amount of water allocated to it under the treaty. India also blames Pakistan for its water woes that India says are emanating from poor management of water resources (Akhtar, 2010). India's narrative on water dispute with Pakistan is that reduced flow of water into Pakistan from time to time is not the result of any violation of the IWT by India or any action on its part to divert river flows or to use more than assigned share of water from the Western rivers. Instead, water flows in the rivers depend on melting of snow and quantum of rainfall. Further, any drop in the flow is also because of the overall pattern of receding glaciers and climate change (Dikshit, 2010).

Further, Indian official sources and the media attribute Islamabad's water woes to "mismanagement of water resources", "less storage facilities" and a "huge 38 MAF of waters flowing every year unutilized" into the Arabian Sea. They also argue, since rivers flowing in (Pakistani) northern Punjab don't provide adequate waters to lower riparian, thereby, Pakistan "attempts to divert attention from growing discontent in Sindh and Balochistan over denial of their share of Indus waters (Shaheen, 2010)." Also as the "population in Punjab increases, the demand for irrigation also increases" (*The Kashmir Times*, 2010). As a corollary, India wants Pakistan to look inwards to address its water issues and improve its water management (Dikshit, 2010). The Indian media is reinforcing the official standpoint. *The Tribune* wrote that Pakistan wanted "to divert public attention from the recurring water scarcity in many parts due to mismanagement of its resources," and "escape criticism for giving preferential treatment to north Punjab by depriving water to some states and for its failure to build and maintain adequate storages to meet shortages" (*The Tribune*, 2010).

India has been tied to the details of the IWT, the text of which largely defines its responsibilities as an upper riparian (Sinha, 2008). India has adhered to the IWT stipulations on water works in J&K for the past 50 years, constructing strictly run-of-the-river projects on the Chenab, Jhelum and

Indus rivers, which it is permitted to do. India is well under the storage capacities set aside by the IWT for agricultural, power and incidental usage. Pakistan's fears about Indian manipulation of water resources are based on a "lower riparian anxiety complex" (Bakshi and Trivedi, 2011). In spite of its hydrological position, India has discounted water as a military tool and target, even in times of outright war, and has abided by the rules of war in a way that does not contravene the Geneva Conventions.

Decision and policy makers in India often argue that going to war is too expensive a proposition for a state wishing to acquire or control a low-value commodity like water. In addition, they argue that India has the reputation and image of a responsible country, which would rather safeguard than violate international treaties and norms. The other realistic assessment is that India has no storage facilities on the rivers designated to and flowing into Pakistan, and thus is in no position to withhold waters. For any aggressive action, India would need to build storage facilities on the three western rivers - Indus, Jhelum and Chenab - a time-consuming and easily detectable task involving heavy expenditure. Any efforts to flood Pakistan would mean flooding areas on the Indian side first, to disastrous consequences. Moreover, the natural hydraulic gradient allows for water to flow easily towards Pakistan (Sinha, 2008).

Regarding the IWT, India mainly has three concerns related to water diversion, terrorism and aid. It is because of these reasons and concerns that water war is not an option for India. Water diversion or storage facilities have a long construction time. The interval between 'the expression of threat' and the 'execution of threat' leaves time to initiate a settlement (Swain, 2004). The time factor also allows the party to prepare itself to face a possible water scarcity situation; and can help highlight the issue at international forums and bring in other actors to arbitrate or mediate in the matter and thus internationalize the issue. India has always been careful because of the World Bank being the third party. Apart from the international obligation and nation's credibility, there is considerable risk attached to building dams and storage facilities that do not abide by the treaty. Such projects might pre-empt the downstream riparian - in a desperate act or irrational moment - to damage the dam, even though it will itself be flooded.

Terrorism is another concern attached to this. Dams and other installations could become targets or tools of violence or coercion by non-state actors. A third and important aspect relates to aid. While India can undertake projects on its own, it would find it extremely difficult to garner any external support, particularly from the World Bank and particularly on disputed projects on international river basins. India will not be keen to undertake the building of storage facilities that contravene the treaty and to suffer international condemnation and loss of aid (Sinha, 2008).

The Indian view regarding the potential of waging 'water war' with Pakistan on water issue was clearly made out by Indian High Commissioner Sharat Sabharwal while addressing an event in Karachi. He said that reduced flow of river waters into Pakistan are not the result of any "violation of Indus Waters Treaty by India or any action on our part to divert such flows or to use more than our assigned share of water from Western rivers" (Ali, 2010). Sabharwal further pointed out that water flows in rivers depend on melting of snow and quantum of rainfall and the quantum of water in the Western Rivers varies from year to year, "dipping in certain years and recovering in some subsequent years" (Joshua, 2010). While pointing out that the flow of the Chenab, after entering Pakistan, had dipped from 48,242 cusecs in 1999 to 22,991 cusecs in 2008, he expressed that, "We have never hindered water flows to which Pakistan is entitled, not even during the wars of 1965 and 1971 as well as other periods of tense relations and we have no intention of doing so" (Joshua, 2010).. He further added "Those who allege that India is acquiring the capacity to withhold Pakistan's share of water completely ignore the fact that this would require a storage and diversion canals network on a large scale. Such a network simply does not exist and figures nowhere in our plans" (Joshua, 2010).

M.S. Menon a leading columnist associated with the Indian Express newspaper group, in an editorial published in *The Hindu* in June 2005, expressed his views regarding issues and concerns of Indus water sharing in India. As per his views, India's hydro projects in Jammu and Kashmir are under threat. Citing gross violations of the Indus Waters Treaty (IWT), he wrote that Pakistan is taking every opportunity to attack these projects to build up international opinion against India. Interestingly, the same treaty is depriving India of its legitimate share of Indus waters needed to meet the increasing demands of the co-basin states of Punjab, Haryana and Rajasthan. He is of the opinion that there are many unreasonable provisions in the treaty to which India had agreed in the interest of peaceful neighbourly relations and early settlement of disputes with Pakistan. But the accommodating spirit with which India had been approaching Pakistan to utilize this share of Indus waters as per treaty provisions has been considered a weakness by Pakistan emboldening it to make more demands to delay Indian projects (Menon, 2005).

The Indian policy makers and security apparatus dismiss the Pakistani view that the ongoing and pipeline Indian power

projects could reduce water-flows to Pakistan or to release stored waters and cause floods. The Pakistani objections are thus partly water-related and partly security-related (Iyer, 2010b). The public view in Pakistan was that India was somehow trying to dam the Chenab River, which was Pakistan's by virtue of the IWT, whereas Indians viewed Pakistani objections as yet another example of Pakistani negativism about any legitimate Indian project on the three western tributaries (Sinha, 2006).The dispute was a manifestation of the different interpretations the two countries' engineers had of the treaty (Iyer, 2010b).

c. Concerns of Kashmiris on Water Sharing and IWT

Despite being the dominant upstream riparian of the Indus, there is a strong sense of grievance in Jammu and Kashmir that the treaty has deprived the state of its huge hydroelectric potential (Briscoe, 2010), making it very difficult for the state to derive any major benefit by way of irrigation, hydroelectric power or navigation from the rivers that flow through it but stand allocated to Pakistan (Iyer, 2008). The Kashmiris are complaining that the Indus Water treaty (IWT) between India and Pakistan has deprived them from using the water flowing through their own land (Ashraf, 2012). The sharing of water has thus become one of the major irritants between India, Pakistan and the Kashmiri people (Khan and Shakir, 2011). The people of Kashmir are vehemently against the IWT treaty, which according to them has made them a sacrificial goat. Kashmir annually looses 60 billion Indian rupees (US$1.3 billion) on account of the prohibitions of this treaty by virtue of which Kashmir cannot store water for generating electricity or for irrigation purposes (Mirani, 2009).

There is growing resentment amongst the people of the state over the government's failure to harness the enormous hydroelectric power potential. Provincial parties in Jammu and Kashmir continue to raise concerns that the treaty is 'extremely unfair'. The state government and some individuals have been seeking even the abrogation of Indus Water Treaty (Din, 2009). The National Conference government, even submitted a memorandum urging New Delhi to abrogate the treaty in the best interests of Kashmir (*Times of India, 2002*). In the past also, the treaty has invoked heated discussions in the legislative assembly during the Peoples Democratic Party (PDP)-Congress rule. Jammu and Kashmir Assembly passed a Resolution on 3 March, 2003 asking New Delhi to reconsider Indus Water Treaty so as to safeguard the interests of the state. According to this report, Pakistan's opposition to the development of hydropower under the Baglihar project amounts to playing with aspirations of the Kashmiri people. It states that average annual flow of water in the eastern rivers allocated to India is around 33 MAF and in the western rivers given to Pakistan is 135MAF (*J&K Insights*, 2005).

With the construction of Baglihar and Kishanganga hydro-electric power projects by India, the issue of Kashmir has been brought at the centre stage of the Indus water issue. In case of both these power projects, domestic pressure from the people and polity of Jammu and Kashmir is an important factor. The Indus Water Treaty has ill-effects on the Jammu and Kashmir's energy harnessing potential and it creates challenges for the setting up of new power projects in the state. "Jammu and Kashmir is facing acute problem on harnessing its hydropower potential due to the restrictions of the IWT. People complain that for every hydropower project, a clearance from Pakistan needs to be sought and despite fulfillment of all formalities, objections from the other side never end. There is a recurring loss of Rs 265 crore annually in Baghliar due to IWT and the total losses are over Rs 3325 crore on Chenab basin. India surrendered rivers originating from the Kashmir to Pakistan at the cost of J&K's interests. The eastern states are progressing at the cost of Jammu and Kashmir". These are the views that were expressed by Zahoor Ahmad Chat-Executive Director J&K State Power Development Corporation at a hydropower conference in J&K (Ali, 2012).

It is pertinent to mention here that the state has an identified hydropower potential of 20,000 MW and out of which only 2365 MW stands harnessed. Bulk of this hydropower, about 1560 MW is generated by NHPC providing a royalty of 12% to the state (JKSPDC, 2012) . In the past two decades, an amount of 40 billion Indian rupees has been invested in the power sector in the state mainly through the NHPC. The people feel that in the absence of the required finances for harnessing the hydropower potential, the central government is exploiting their financial backwardness and encourages NHPC as the major hydropower producer of the state. This sentiment is supported by the argument that the central government has several times stymied the bilateral and multilateral funding opportunities for hydropower generation in the state by refusing to extend the guarantee as is mandatory for the external funding.

The demand of energy continuously goes on increasing year after year in the state. Thus, huge portion of the state budget is utilized in purchase of power from various agencies outside the state. Keeping in view the current power scenario in the state, there is a distinct possibility that energy shortages in the state would grow and impose a heavy economic and social cost on its people. The state is facing huge power deficit and incurs an expenditure of Rs. 33,000 million on power purchases despite this huge hydropower potential. The

people also blame the successive state governments for the failure to develop strategies and a roadmap to harness this hydropower which could have given a boost to the economic and human development of the state. After meeting the domestic, industrial, agricultural and other demands of the state which as of now is about 2000 MW only, people argue that the balance power can be exported and the earnings out of such sale will be many times more than the annual budget of the state.

Recently, some civil society groups have organized several workshops and are clamouring for compensation of losses incurred by the state due to the restrictions imposed by the IWT on hydropower generation and some of these groups are, in fact, asking for re-negotiating the treaty to the benefit of the people of Jammu and Kashmir. The successive state governments have failed to develop a strategy or roadmap to develop the identified hydropower in the state. People believe that, if the power potential of the state is fully exploited, the state would be in a position to meet its own demand and even bail out central government and neighboring states by providing the surplus power and inter alia generate huge earnings for the state that would be utilized for economic and human development. There are some suggestions that in order to protect the forest cover in the UIB, which is very vital for prolonging the life of the hydropower infrastructure in Pakistan, that Pakistan should be asked to compensate to the people of Jammu and Kashmir so that the money could be used for soil and water conservation measures in the UIB. The payment of environmental cess or any other compensatory financial instrument is an internationally accepted norm under upstream-downstream rights and responsibilities doctrine.

The IWT permits Jammu and Kashmir to use the waters of the rivers covered under the treaty to irrigate only 17.03 lakh acres of land. Along with the running water irrigation potential of 13.43 lakh acres, IWT also permits J&K to irrigate 3.6 lakh acres through storage of water. However, the state is utilizing the waters of three rivers- Chenab, Jehlum and Sindh - to irrigate just 8 lakh acres. There is a huge gap of unutilized water exceeding 9.00 lakh acres, which J&K has over all these years allowed to flow down for its failure to utilize the same (Azad, 2012). In fact, the areas under irrigated agriculture are consistently decreasing in the state due to the rampant land system changes from water intensive paddy culture to horticulture.

1.4 Which interest groups have which concerns, and how are they defined?

India and Pakistan, the key players on sharing of water governed by the IWT, face similar problems in terms of floods, droughts, inefficient management of water resources, depletion of ground water and pollution of these precious resources. The two countries face similar, precarious predicaments. However, presently various groups have their interests in the complex equation of water sharing between India and Pakistan. These interest groups include government agencies, media, academicians, different groups, members of civil society and farmer groups from both sides. These interest groups can be categorized into two groups or categories - the first category would constitute those who politicize the water discourse in both the countries (the elite preferences), while the second category would include those potentially affected groups or those engaged with the water discourse, for example civil society, community groups, affected people, academia, think tanks etc. Basically the key players involved in the treaty are India, Pakistan and the state of Jammu and Kashmir. So the governments of both the countries, including the opposition parties, are fully involved in the water sharing issues.

Apart from the various government agencies and members of the society the radical and extremists groups from both countries have their interests vested in the complex issue of water sharing and the IWT. Some believe that as the gap between water availability and requirements widens, terrorist operations and recruitment in the region will follow (Waslekar, 2005). Asif Ali Zardari, Pakistan's President, stated: "The water crisis in Pakistan is directly linked to relations with India. Resolution could prevent an environmental catastrophe in South Asia, but failure to do so could fuel the fires of discontent that lead to extremism and terrorism." (*The Telegraph* on March 26, 2009).

In 1960, both governments were happy to sign the Indus Water Treaty, but currently the public reaction to this treaty is very different. People in Pakistan criticise the loss of three eastern rivers, despite the huge amount of financial aid Pakistan received in lieu of this loss. In India also some sections of the public criticise the loss of its three western rivers. Recently, the people of Kashmir have started vehemently criticizing the treaty as they feel that it was signed without any consultation and representation from the people of Kashmir. In Pakistan, the political situation has been, most often, a fragile balance between different interest groups, which put conflicting demands and pressures on the central government, all of which produces a political climate of confusion and conflict (Tayyeb, 1966).The government and political leadership in Pakistan have been quite vocal in expressing their concerns regarding any Indian water initiative under the Indus Water Treaty, especially the hydropower projects on the Jhelum and Chenab rivers. In October 2008, shortly after filling of the

Baglihar dam that caused reduction in Chenab's waters into Pakistan, President Asif Ali Zardari asserted that, "Pakistan would be paying a very high price for India's move to block Pakistan's water supply from Chenab River." He warned India "not to trade important regional objectives for short-term domestic goals" (Subramanian, 2008).

Even opposition members of both governments criticise the Indus Water Treaty as and when it enters into a political discourse. Even the water experts from both countries, more so in Pakistan, are not happy with the treaty. Consequently, both governments are facing immense pressure from different groups of society. The underlying concern of governments in both the countries is the political aspect that water entails (Wasi, 2009). Wasi says that this aspect is believed to be the catalyst behind the hydro-politics in which both countries are getting engaged. Political considerations of course cannot be ignored while dealing with the water issue on technical grounds, especially keeping in mind the distrust in India-Pakistan relations and their history of antagonism.

Quite often, farmers in the agricultural heartland of Pakistan blame India for decreasing river flows and groundwater levels in the Lower Indus basin. This clearly highlights the concerns of farmers living in an agricultural heartland of Pakistan regarding the IWT and issues of dam construction. Pakistan Muttahida Kisan Mahaz, a farmer's collective, has urged the Pakistani government to approach the World Bank against India's construction of dams on the western rivers (*The Nation*, 2010). The Kisan Mahaz has released a joint communique stating that 80 per cent of the farmers had been affected due to stealing of the water of rivers Jhelum, Chenab and Indus by India as result of building dams. It has also alleged that Pakistan's agriculture would suffer losses of billions of rupees besides a threat of famine due to shortfall in river water supply (*Dawn*, 2009). The Mahaz, which emerged as the lobby group for farmers in Pakistan, has also been aggressively advocating the construction of dams in Pakistan, in order to generate more electricity from hydropower. Riaz Haq (Founder and President of Pak Alumni Worldwide, a global social network for Pakistanis) asserts that there is in Pakistan the fear of growth in social discontent, terrorism and instability from the potential ravages of water scarcity in the form of crop failures and poverty. However the farmer's organizations have also tried to establish linkages to build the environment against water wars. The Punjab Water Council, a collective of farmers in Punjab, for instance has emphasized the need for "talking" water with India. Arguments are based on the fact that talks could assuage Pakistani fears that Indian hydroelectric stations could run Pakistan's rivers dry. These collectives have further stated that, "If diversions like the Kishenganga project are not settled as it should be, then we have serious apprehensions that diversions from other rivers would also be made and precedents would be set" (*Daily Times*, 2010). Various political parties have also articulated such concerns on water shortages (Gupta, 2010).

Pakistan complains that India was withholding millions of cubic feet of water upstream in Indian-administered Kashmir and storing it in the massive Baglihar dam in order to produce hydroelectricity. However, the Pakistani concerns on reduced flows and its blame on India is being dismissed in light of some scientific findings that suggest that the changes in the Himalayan cryosphere and the demography have significantly reduced the river flows emanating from the Upper Indus basin.

The key grievances and their rebuttal articulated by various groups in India and Pakistan revolve around the construction of dams - Baglihar and Kishenganga. These concerns are basically related to food and energy security, but have also been linked to territorial security and integrity and its linkages to the Kashmir rhetoric. Inside Pakistan, political mobilization on dam construction on the western rivers has stoked anti-India sentiments among farmers associations, politicians, fundamentalist groups and the army. Specific statements on India's water aggression have been issued by these pressure groups at various points of time. Defense and tactical reasons are some other arguments that have shaped perceptions, thus linking the debate regarding dams to hostile Indian intentions (Bisht, 2011).

Important groups or stakeholders contributing to the water discourse in Pakistan are the army, jihadists, politicians and other hardline groups representing farmer's organizations, and also engineer's forums. Another group concerned with the issues of IWT in Pakistan, attributing the water crises in Pakistan to the building of dams in India, is the Engineers Study Forum, a water expert's panel. According to a report released by the panel, India is stealing 15 to 20 per cent of water from western rivers, causing $12 billion loss to agriculture in Pakistan. It further adds that the total water availability of the western rivers is 125.6 MAF, out of which India steals a big chunk of water imposing economic cost in terms of agricultural loss to Pakistan. The loss is estimated at $12 billion per year (*Pakistan Daily*, 2010).

The Pakistan army's response to the Kishenganga dam is directly related to strategic considerations. This is evident from General Ashfaq Kiyani's statement during the Pakistan-United States strategic dialogue in March 2010, when the General raised the issue with US officials (*Dawn*, 2010). The Pakistani official was quoted in the media as stating that,

the Pakistan army was an "India-centric institution", and the "reality will not change in any significant way until the Kashmir issue and water disputes are resolved" (*The Hindu*, 2010). This ascent of water as a core issue along with Kashmir by Pakistan's military establishment highlights the strategic aspect of equating water with Kashmir.

In Pakistan the extremist groups, led by Lashkar-e-Toiba (LeT) supremo Hafiz Sayeed, have declared water war or 'water jihad' on India. Extremist organizations like Jamaat-ud-Dawa (JuD) have tried to use it to invoke anti-India emotions in the general public. Pakistan's banned 'jihadi' publications like *Jarrar* (a publication of Jamaat-ud-Dawa), *Zarb-e-Momin* (a publication of Al-Rasheed Trust) and *Al-Qalam* (a publication of Jaish-e-Muhammad), have started highlighting this issue as "water terrorism." These organizations have devoted a portion of their publications to highlight the Indo-Pakistan water issue, urging people to get ready for jihad against India over water (Gillani, 2010).

Linking Kashmir to water suits the interests of political parties in as much as it helps divert debate away from domestic terrorism, political instability, inequitable land holdings, water scarcity, poor water policies and provincial conflicts on water rights within Pakistan (Gupta, 2010). Recently Yusuf Raza Gilani, Pakistan's Prime Minister, put the water issue at par with Kashmir, stating that, "We want the world to concentrate so that we resolve all our core issues including Jammu and Kashmir and water with India" (*Dawn*, 2010). *Dawn* quoted the former Foreign Minister, Sardar Asif Ali as saying that, "if India continues to deny Pakistan its due share, it can lead to a war between the two countries" (Dawn, January 18, 2010). PML (Q) Chief Chaudhary Sujat Hussain said that the water crisis between Pakistan and India could become more serious than terrorism and can result in a war (*Dawn*, January 18, 2010). Majid Nizami, Chief Editor of the Nawi Waqt group of newspapers, said that, "Pakistan can become a desert within the next 10 to 15 years. We should show upright posture or otherwise prepare for a nuclear war" (*Dawn*, January 18, 2010). Members of the Punjab Assembly passed a resolution to deny India trade transit facility until the resolution of the Kashmir dispute and issues related to water distribution (*Dawn*, January 27, 2010). Member of the Punjab Assembly, Warris Khalo, said that India would "remain an enemy" until the Kashmir dispute and water issues are resolved (*Dawn*, January 27, 2010). Palwasha Khan, Member of National Assembly, accused India of perpetrating "water terrorism" against Pakistan and said that, "experts foresee war over the water issue in the future and any war in this region would be no less than a nuclear war" (*Daily Times* February 17, 2010).

In a recent debate in Pakistan's National Assembly, several members urged the government to impress on New Delhi "not to use" Pakistan's share of water (*Daily Times*, February 25, 2010). Dr Manzur Ejaz, a commentator, writing in *Daily Times* (March 3, 2010) warned that, "unless Pakistan was assured on the supply of water, it will never abandon the proxies that can keep India on its toes by destabilizing Kashmir." He further added: "For Pakistan the territory of Kashmir may not be as important as the water issue." These comments clearly indicate that water can be an issue of great emotional power to mobilize the Pakistani people that can have a cascading effect on India-Pakistan bilateral relations (Iyer, 2008).

The Indus Waters Treaty was meant to reduce hostilities between India and Pakistan. It has failed to do so and, in fact, is being used by the jihadists and Pakistani media to whip up hatred against India (Thampy, 2012). In India, the hawks have demanded the stopping of the release of Indus River system water to Pakistan. Not belonging to either group, there are some who advocate for another treaty to replace the existing Indus Water Treaty, 1960 (Ranjan, 2012). Due to the conflicting interests, the radical elements from both the countries publicly demand scraping of the treaty, without realizing the side effects or the rationality of their demand (Ranjan, 2012). In spite of being one of the two successful treaties between India and Pakistan (the other being sharing details of the nuclear installations and facilities under India-Pakistan Non-attack Agreement, signed on 31 Dec., 1988 during late Prime Minister Rajiv Gandhi's visit to Islamabad [NTI, 2011]), this treaty needs some supplemental support to address some of the emerging and anticipated concerns about the increasing demand of limited water supply to fulfill agricultural, industrial and domestic consumptive demands of increasing population of the Indus River system catchments areas. Also the phenomenon of climate change is impacting the cryosphere and water flows downstream. Despite several divergences, the two nations have convergent concerns about the food security, energy security, environmental degradation, climate change and future water scarcity. The best way to deal with the Indus water issues is to jointly look into problems of the entire Indus basin, which could materialize only if there is political will on both the sides. The collaborative understanding of the system may, in due course of time, when the political relations between the two countries improve, finally lead to the joint management of the basin. This envisages persistent efforts at the governmental and non-governmental level to bring all the stakeholders and interest groups onto a common platform. This will surely help in better understanding each other's concern and in clearing the misgivings and building a consensus on how to address the emerging issues related to the smooth implementation of the Indus Water Treaty (IWT).

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CHAPTER II

Defined Concerns

Summary: *This chapter discusses a number of well-defined concerns, based on scientific observations, knowledge and informed data analysis, that affect the usage and distribution of water resources between India and Pakistan. The material and discussion in this chapter has been organized into the following specific topics:-*

e) Observed historical changes in the water flows in the Upper Indus Basin (UIB)

f) Demographic changes in the UIB basin and their impacts on water demand

g) The historical changes in the land use and land cover in the UIB and its impacts on the water resources (including irrigation)

h) Technical and managerial issues related to the sharing of trans-boundary Indus waters

i) Depletion of groundwater resources in the Indus basin

Conclusions about each of the above concerns are based on the scientific analysis of the available data from various sources in the Jhelum basin. The stream-flows are showing statistically significant decline in most of the watershed in the Jhelum basin due to the shrinking cryosphere and other hydrological changes in the basin. Due to the tremendous socio-economic transformation in the Jhelum basin, the demand for water for drinking and other domestic purposes has increased significantly. Concurrently, several changes in the land cover have been observed in the Jhelum basin that has an impact on the usage of available waters. The causes and consequences of the depleting groundwater resources in the entire Indus basin are also discussed in detail in this chapter, in light of the secondary information available in the two countries.

2.0 Introduction

The Indus Basin with its complex geopolitical position is considered to be one the most depleted river basins in the world (Sharma et al. 2010). For centuries this river basin has been the lifeline of cultures, food production, livelihoods and biodiversity spanning across borders. The Indus Basin ranks among the largest basins of the world in terms of human dependence on irrigation waters sourced from the river water. The river supports a population of about 215 million people (UNEP, 2008), whose livelihoods rely directly or indirectly on the river basin resources. As elsewhere in the world, and more particularly in the two countries of Indian subcontinent, where the teeming populations and worsening environmental degradation continue, demand for water continues to rise and the supply from the river is no longer sufficient to meet the demand.

High population growth in the downstream region and growing impacts of climatic variability upstream have produced increasing stress on the water supply available from the Indus River. The lower part of the basin is now one of the most water-stressed areas in the world and is likely to become a water-scarce area soon if the current trends continue (Briscoe and Qamar 2005). Rapid urbanization and industrialization, environmental degradation, unregulated utilization of the resources, inefficient water use and poverty are the major concerns in the basin (Laghari et al. 2011). The groundwater is being exploited unsustainably, but its use is still expanding, creating large regional negative water balances (Sharma et al., 2010). Falling water tables (Rodell et al. 2010) have also created an unviable nexus between water and energy (Scott and Sharma 2009). Given the depleting resources of water, the issues of human security and water security are going to assume astronomical proportions. Further anomalous weather episodes such as the exceptional floods experienced in 2010 may increase the risk of the people and property to flooding, droughts, or both in the basin.

Of late issues like transboundary distribution, utilization and management of water, together with construction of large-scale irrigation/hydro-electric power projects affecting the upper and lower riparian areas have taken centre stage in defining interstate

relations. Many regions in the two countries are beginning to experience moderate to severe water shortages, brought about by the simultaneous effects of agricultural expansion and growth, industrialization, urbanization and population growth. The issues of water distribution and management are pushing not only countries of the region into conflict, but also provinces and regions within the provinces in both the countries since they are not being settled amicably within a grand framework of riparian statutes respecting upstream and downstream rights. With the threat of climate change looming large, observed changes in the form, intensity and timing of precipitation with variable snow and glacier melt will increasingly challenge food security and the livelihoods of the people living across the basin.

The Indus basin is already suffering from severe water scarcity (WRI, 2003) and differences over water sharing issues continue to create ill-will between the two neighbouring countries sharing the Indus basin. Despite the Indus Water Treaty that survived the coldest of the relations between India and Pakistan, serious differences over water sharing, water management and hydropower projects continue to spoil relations. During the last two decades diverge national views have emerged about the interpretations of different clauses of the Indus Water Treaty. Besides the many issues of water sharing, several water and energy related issues are critically affecting the food security, environment and agriculture in the basin. It is, in this context that water security is emerging as an increasingly important and vital issue for both India and Pakistan.

Over the years, various studies conducted in the basin have been limited by national boundaries. Several aspects of the Indus basin have been researched visa-vis its hydrology and available water resources (Winiger et al., 2005; Archer, 2003; Immerzeel et al., 2010; Kaser et al., 2010); impact of climate change on glaciers and the hydrological regime (Akhtar et al., 2008; Immerzeel et al., 2010); agricultural water demands and productivity (Cai and Sharma, 2009; Cai and Sharma, 2010); groundwater management (Kerr, 2009; Qureshi et al., 2009; Scott and Sharma, 2009; Shah et al., 2006); reservoir sedimentation (Khan and Tingsanchali, 2009); ecological flows and the Indus delta (Leichenko and Wescoat, 1993); water policy (Biswas, 1992; Miner et al., 2009; Shah et al., 2006; Shah et al., 2009; Sharma et al., 2010) and water resources management (Archer et al., 2010; Qureshi et al., 2009). Most of the studies carried out have focused in a few areas of the basin, and the lack of information sharing among the researchers/policy makers in the upper and lower Indus basin has constrained the scientific studies and thus, impaired the perspective planning on water resources conservation of the basin. Under these circumstances, only a basin-wide approach, irrespective of the political and administrative boundaries, can provide a holistic understanding of the shared water systems for developing a robust strategy for sustaining the available water resources in the region. Creating the possibilities of a collaborative effort to conduct a credible basin wide study of the entire Indus Water System will result in exponential benefits across the board including possibilities of institutional information and expertise sharing, consultation between upper and lower riparian stakeholders and thus, inter alia lead to confidence building and political stability in the region. A few of the defined concerns in the upper Indus basin, mostly Jhelum tributary, are discussed in the following paragraphs to provide the readers a glimpse of the issues confronting the water and land resources development in the basin.

2.1 Historical Stream-Flow Changes in the UIB

In the Indus basin, the Karakoram, Himalaya and Hindu Kush Mountains supply major sources of the flow in the River Indus feeding it by a combination of melted water from seasonal and permanent snow fields and glaciers, and direct runoff from rainfall both during the winter and the monsoon season. For centuries, this flow has formed and sustained lifelines of cultures, food production, livelihoods and biodiversity spanning across vast regions of the Upper Indus basin (UIB) and supplying the water for irrigation and power for large populations living in the downstream plains (Archer 2004). However, there is a significant decrease in the river flows observed both in the UIB and LIB. We here showcase the analysis of the time series of stream flow discharge data from Jhelum River showing significant decreases. Similar is the scenario in many other tributaries of the Indus. The Jhelum, one of the main tributaries of the Indus River forms a major source of water for the Kashmir Valley and is instrumental in supporting the various economic sectors in the region. The river Jhelum receives tributaries from both the southern slopes of the Greater Himalaya and the northern slopes of the Pirpanjal range fed both by glaciers and melting of seasonal snow. The hydrological regime of rivers in such high mountains areas is strongly regulated and influenced by changes in the climate.

In the ecologically fragile mountainous region of Kashmir, changes in the hydrological processes brought about by the changing climate and large-scale land cover changes have far-reaching implications for both the human populations and physical and ecological processes downstream. Many areas in the Kashmir region are beginning to experience moderate to severe water shortages, compounded by the simultaneous effects of urbanization and population growth. Agriculture that is the mainstay of the economy for the Valley, is fast being replaced by horticulture and large tracts of the agriculture lands have been eaten up by the rapid urbanization being witnessed in the region. These large-scale changes in the land system

have started ringing alarming bells as the shrinkage of the agriculture lands has adversely affected the food production. High population growth in the region and growing impacts of climatic change have put increasing stress on the water supplies in the region.

In light of the clear and loud indications of climate change in the Kashmir Himalayan region, an understanding of the changing hydrological set up in response to these changes is necessary for developing a robust strategy for sustainable development of the limited fresh water resources on a short and long-term basis. Despite the tremendous importance of the water resources in the region and its sensitivity to the climate change, very few studies, if any at all, have addressed the issue. Serious implications are expected to occur in light of any change in the magnitude or flow regimes seriously impacting the livelihoods of those engaged in the agricultural and other sectors of the economy as a whole (Archer et al., 2010). Changes in the timing, with or without changes in magnitude, could also have serious implications for water management, especially for the operation of large existing and pipeline reservoirs. Since the Jhelum basin of UIB occupies a complex geopolitical position, the likely impact of the observed and perceived changes in the hydrology and the issues of water resource availability and utilization are expected to transcend environmental and economic dimensions, giving fillip to the political imbroglio in the volatile region.

This subsection provides an abstract and glimpse of the investigations about the trends of the stream flow observations in the Jhelum and its main tributaries using discharge measurements from the Jhelum basin stations. Broad characteristics of hydrological regimes are showcased from the basin using stream flow data for 10 stations on daily, monthly, annual and seasonal basis. The 10 catchments chosen for exploratory data analysis included 2 in the north of Kashmir Valley (Vij and Dakil), one in Central Kashmir (Dachigam) and 7 in the south Kashmir (Bringi at Wayil, Sukhnag at Trikulbal, Batkoot and Odour along Lidder, Sandran at Muniwar, Vishow at Reshnagri and Pohru at Suil). The hydrometeorological data (1971-2010) used for the analysis was obtained from the Irrigation and Flood Control Department. Both parametric and non-parametric tests, Mann-Kendall test, Spearman's Rho test and Linear Regression, were used to assess the significance of the trends of discharge data. The records showed a decreasing trend in discharge for 8 of the 10 evaluated catchments. Vij and Dakil are the only two among the studied catchments that showed an increasing trend in streams flows. The basins showing increasing discharge are charged by not only by precipitation but also by the snow- and ice-melt fed tributaries on their way, implying that significant proportion of the flow is derived from the glacier melt. Figure 2.1 shows the trend analysis of the discharge data for 10 representative basins of the Jhelum basin.

Analysis of the discharge data from two representative watersheds, namely Dachigam and Dakil, that recorded contrasting decreasing and increasing trends respectively are discussed here to make inferences about the entire Jhelum basin.

a) Stream flow Data Trends at Dachigam:

The statistical analysis of the discharge data at Dachigam using the parametric and non-parametric tests in the Dachigam catchment showed a significant decreasing trend. Yearly, seasonal and monthly patterns of the historical observed discharge data are shown in Fig. 2.2. Statistics of tests for the yearly discharge trend at Dachigam shows a significant decreasing trend at the significance level of 0.01 for all the three tests. From the seasonal analysis of the data it is evident that there is significant decreasing trend in the magnitude of seasonal discharge. The statistics show that all the three tests are showing a significant decreasing trend at the significance level of 0.01 in all the four seasons.

Figure 2.3 shows the monthly trends of the stream flow observation data at Dachigam. From the analysis of the monthly data for the Dachigam station, it is evident that all data is showing a decreasing trend for all the months of the recorded observation.

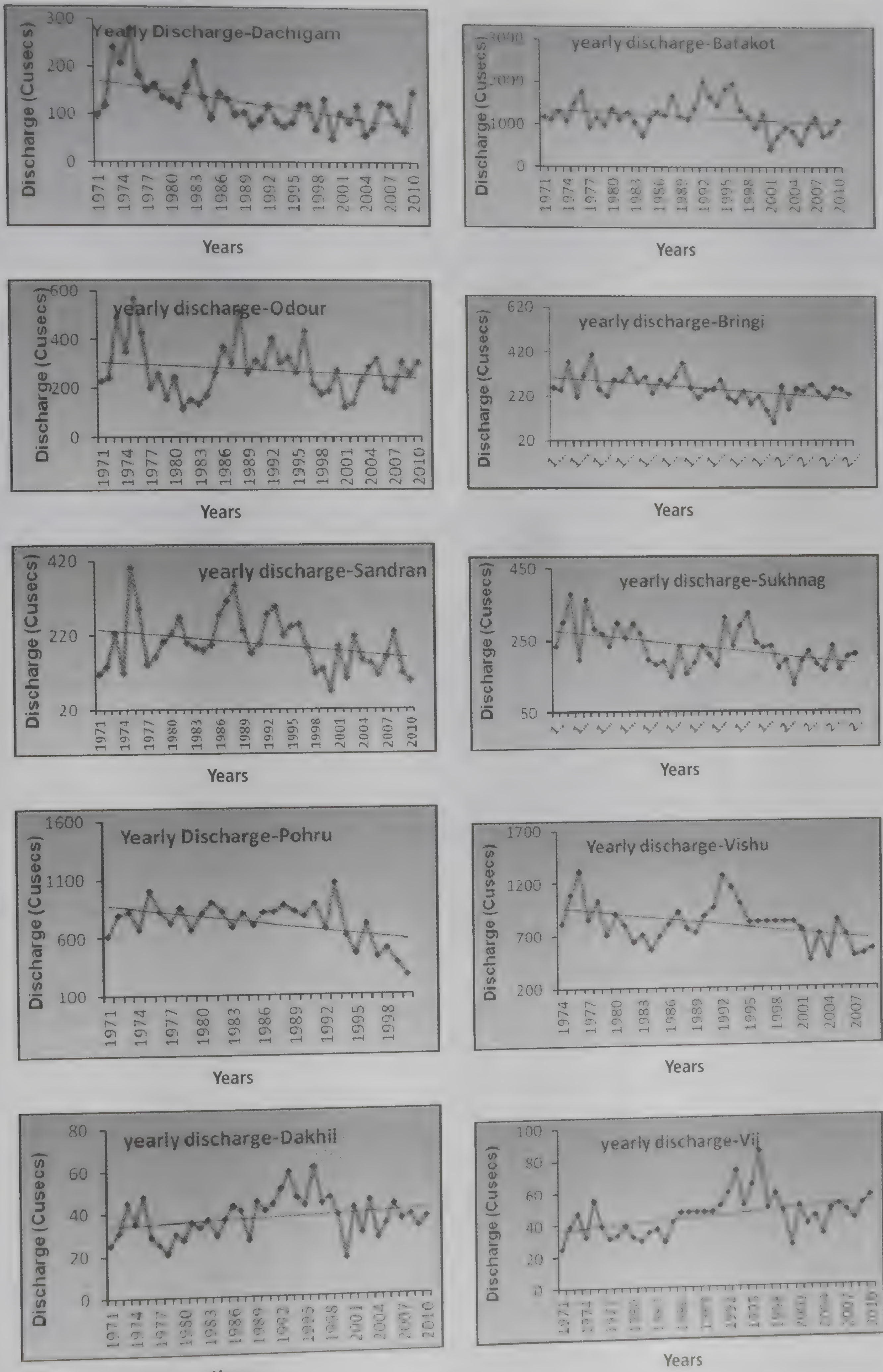

Figure 2.1: Showing the yearly stream flow discharge in some representative basins in the upper Indus Basin

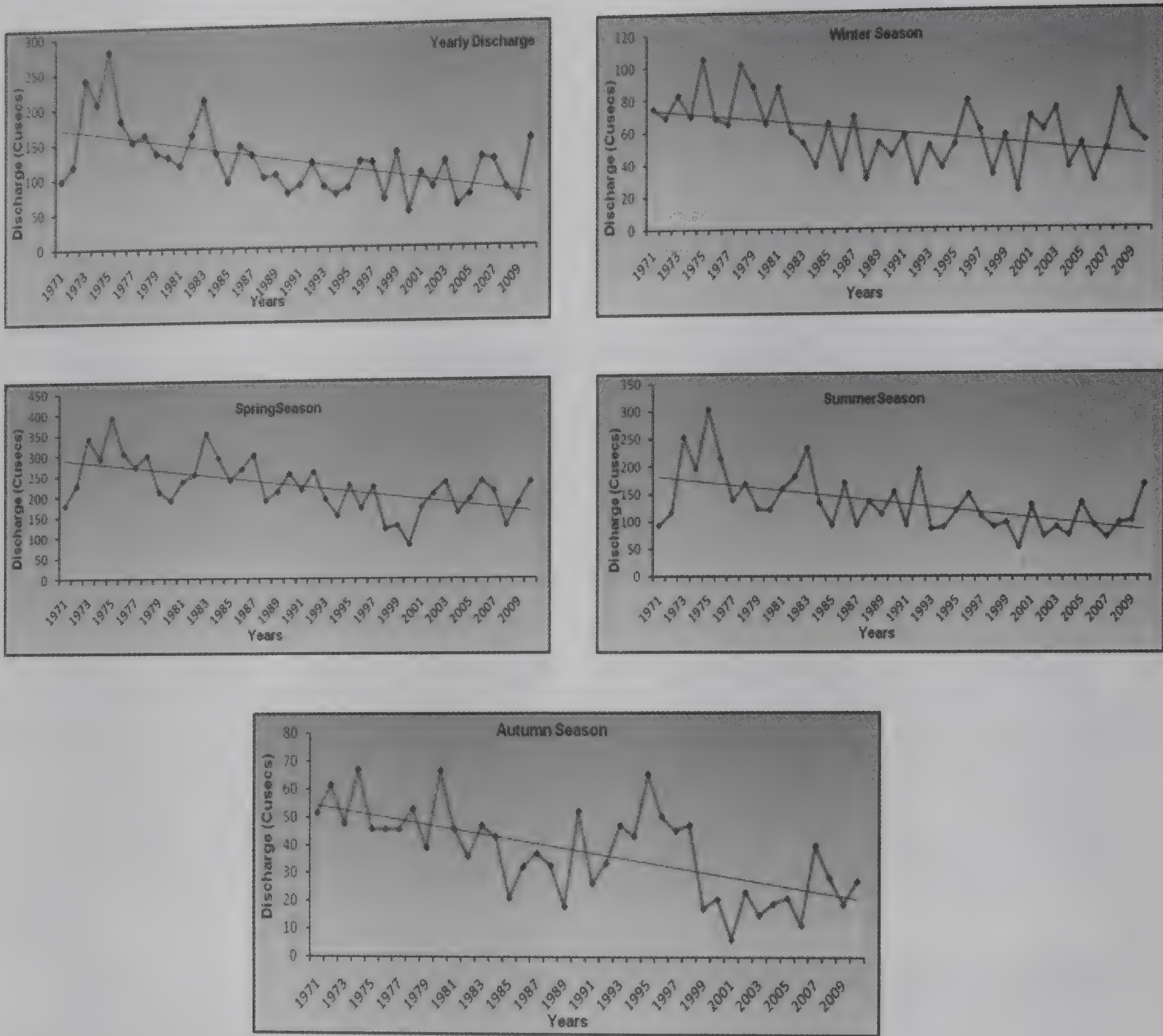

Figure 2.2: Showing the yearly and seasonal stream flow discharge trend at Dachigam in the upper Indus Basin

b) Streamflow Data Trends at Dakil:

The streamflow data observed at Dakil since 1971 was statistically analyzed using the three tests discussed above for trend analysis on annual, seasonal and monthly basis. The streamflow data analysis for the Dakil hydrologic station showed a significant increasing trend, as shown in

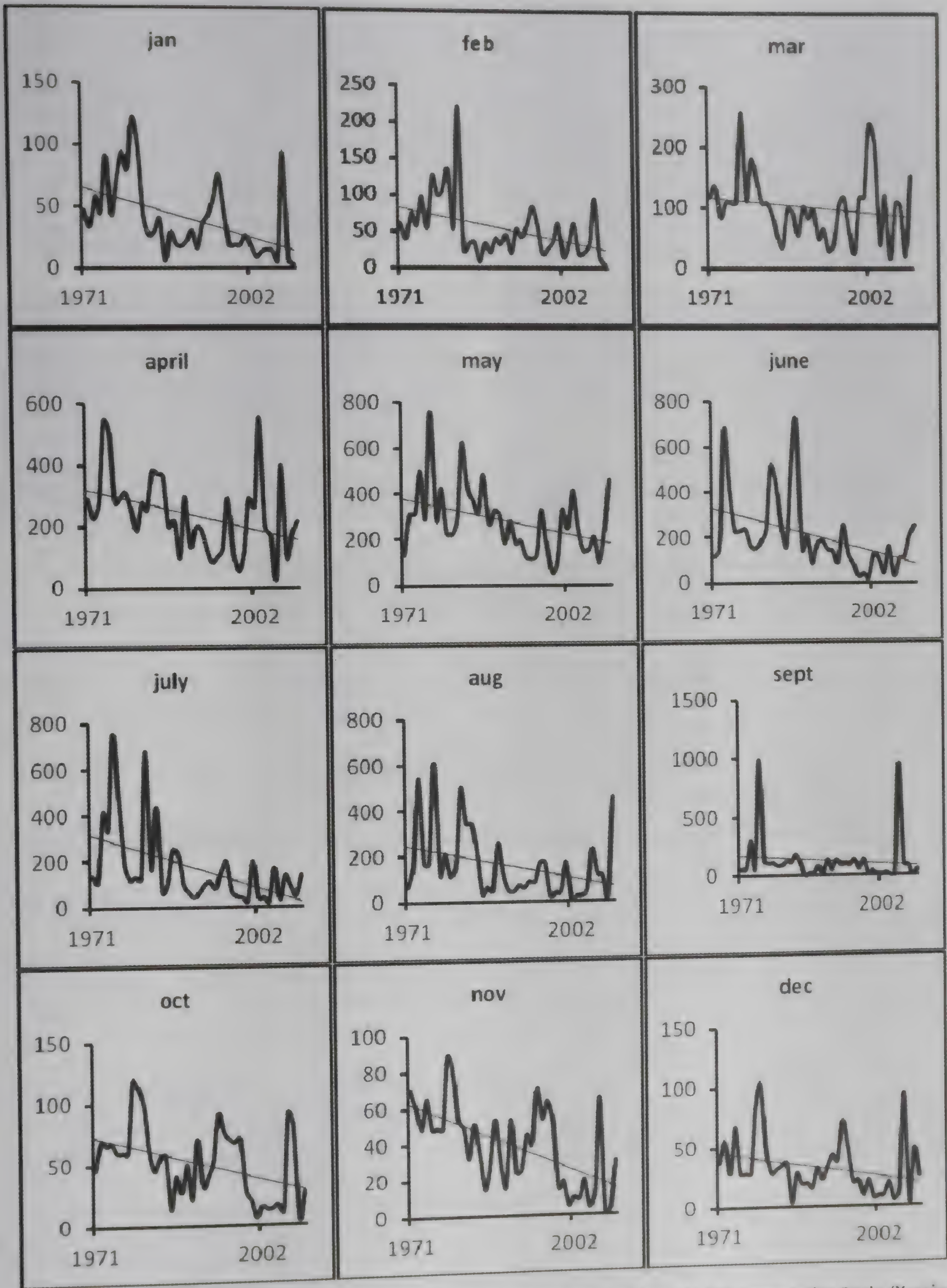

Figure 2.3: Showing the month-wise stream flow discharge trend at Dachigam in the upper Indus Basin (X-axis: years; Y-axis Discharge in Cusecs)

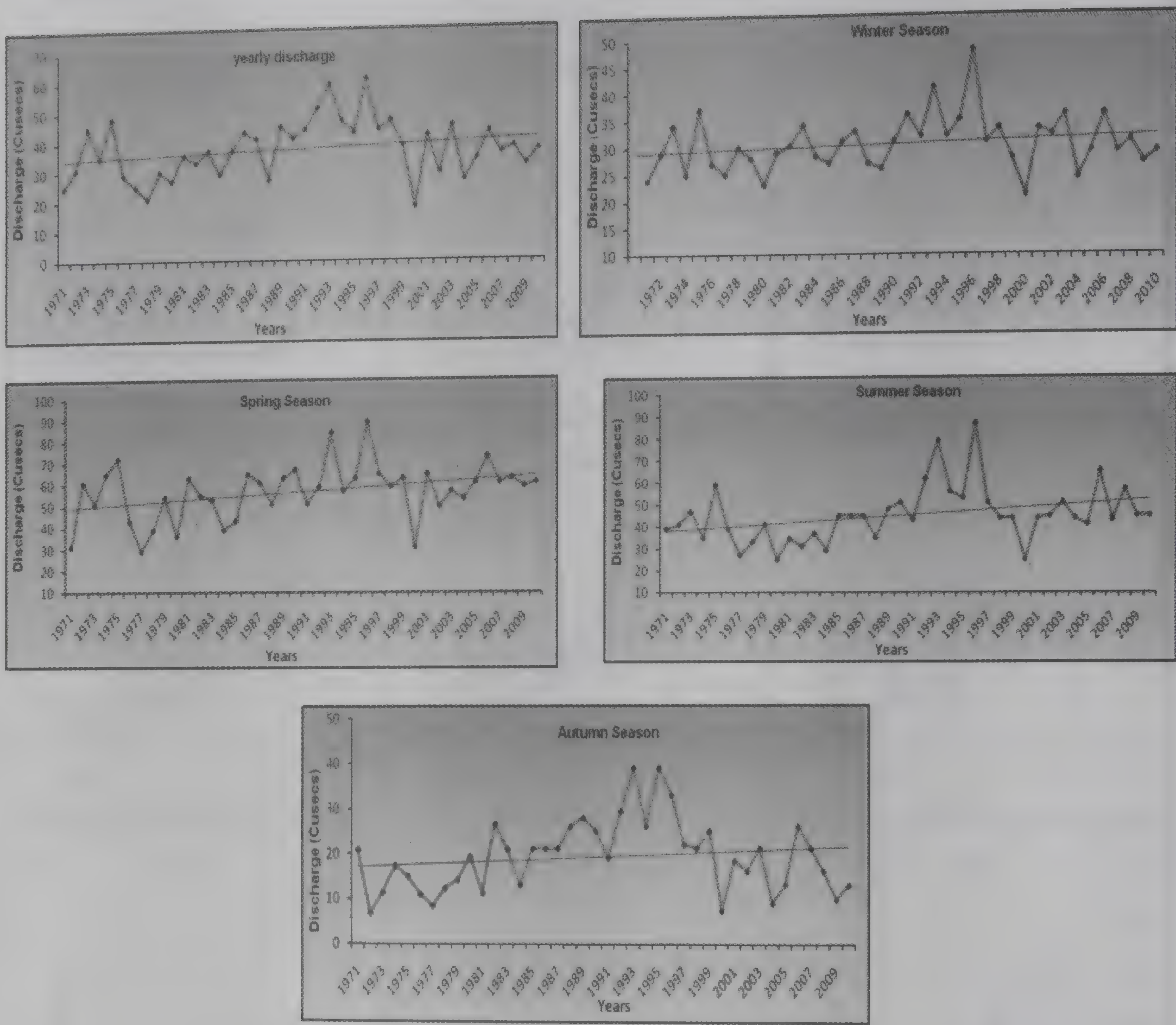

Figure 2.4: Showing the yearly and seasonal stream flow discharge trend at Dakil in the upper Indus Basin

Fig. 2.4, compared to the decreasing trends observed at the Dachigam station discussed above. Test static is positive for all the tests and in all the seasons indicating an increasing trend in discharge. However, the winter season has shown an insignificant increasing trend using all the three tests. Spring season shows a significant increasing trend with a significance level of 90% for Mankendall test, 95% using Spearman's Rho and Linear Regression test. Summer season also shows a significant increasing trend in discharge at the significance level of 95% for Mankendall and Linear Regression test, while the Spearman's Rho shows significance of the increasing trend at 99%.

Figure 2.5 shows the monthly trends of the stream flow observation data at Dakil. From the analysis of the monthly data for Dakil station, it is evident that most of the data is showing an increasing trend for the recorded observation except July, October, November months. For January month, there is almost no trend in the discharge data. From the analysis of the data (Irum and Romshoo, 2012) for ten hydrological stations of the Jhelum in the upper Indus basin, it is clear that eight of these stations are showing a declining trend in the stream flow. Similar decreasing trends have been observed from other stations in the Jhelum (Sumira and Romshoo, 2012)

2.2 Demographic changes in the Indus basin

The population of Pakistan, currently at 185 million, is projected to increase to 246 million in 2025 and 335 million in 2050 according to the medium population estimates (UN, 2011). However, for the year 2050, the different population growth trajectories range from a lower estimate of 293 million to a higher estimate of 459 million. Also, in the Indian part of the basin, population has shown similar increasing trends. In the Indian agricultural province of Punjab, the current population

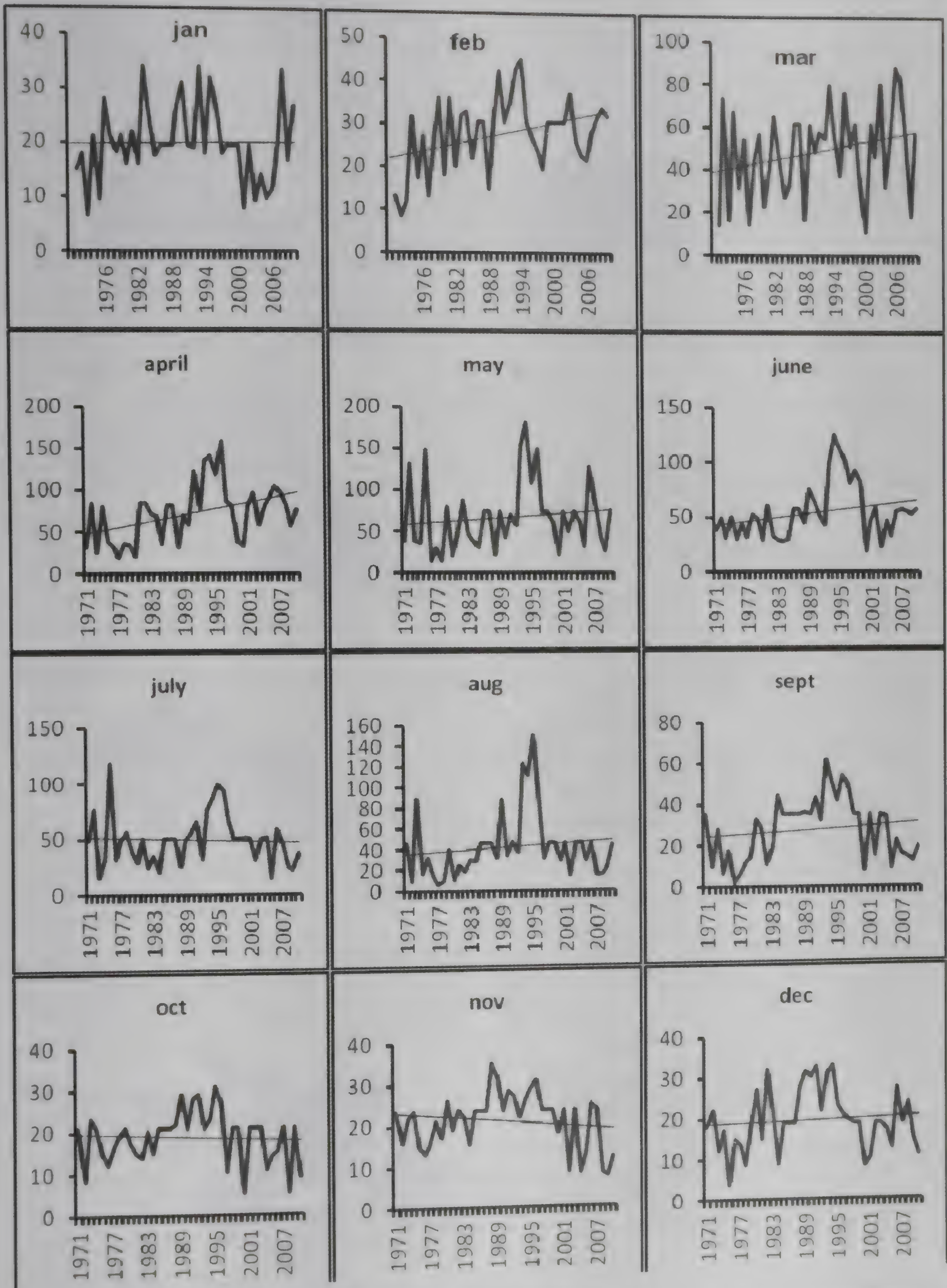

Figure 2.5: Showing the month-wise stream flow discharge trend at Dakil in the upper Indus Basin (X-axis: years; Y-axis Discharge in Cusecs)

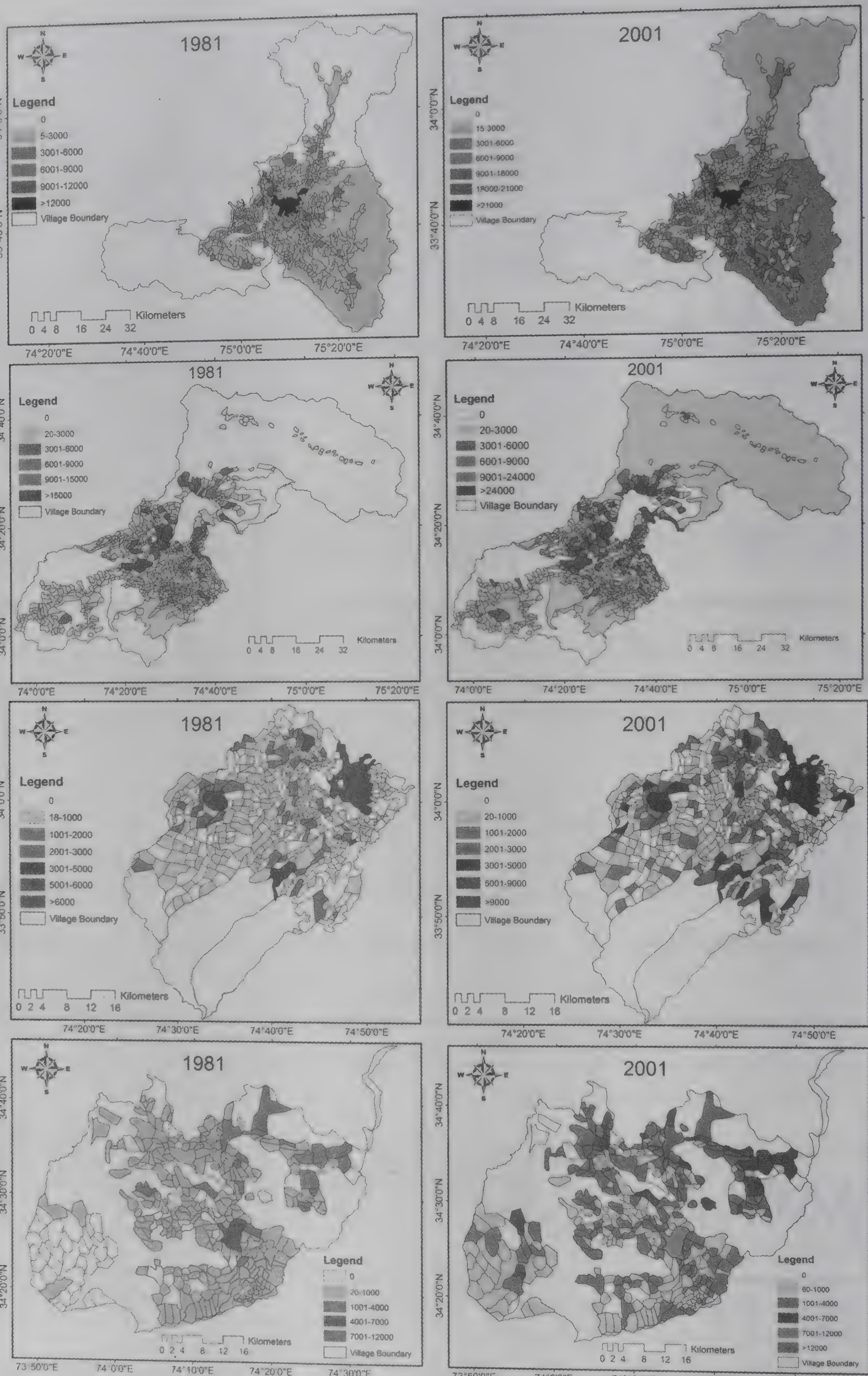

Figure 2.6: Showing the population changes in few districts of the Jhelum basin from 1981-2201

of 27 million (60% of the Indian population in the Indus basin) is projected to increase to 29 million in 2025 (Mahmood and Kundu, 2008). Kabul is located in the Indus basin, and its population has tripled since late 2001, to approximately 4.5 million people, making it perhaps the world's fastest-growing city in the last eight years (Lashkaripour and Hussaini, 2008; Setchell and Luther, 2009). The number of people that live in the Chinese part of the basin are very few because of the rugged topography and inhospitable living conditions. Upper Indus basin in the state of Jammu and Kashmir has also shown a sharp increase in the population growth from 2.14 million in 1901 to 12.5 million 2011. The state has shown a growth rate of about 23% in 2011 compared to the population figures of 10.1 million in 2001.

The population changes in some parts of the UIB that encompasses the Kashmir valley, observed from 1980 to 2001, are shown in the Fig. 2.6. The population increase puts tremendous pressure on the water demand and is one of the reasons for declining stream flows in the Jhelum basin. As a result of this increase in the population, the per capita water availability in the entire Indus basin is decreasing. The per capita water availability in the Lower Indus Basin (LIB) has already dipped below the water scarcity level of 1000 m3/capita. The UN population projection estimates (medium) of 246 and 335 million for 2025 and 2050 respectively will result in per capita estimates of only 711 and 522 m3 respectively (Archer et al., 2010).The World Bank has categorized the basins having a per capita water availability below 1700 m3 per year (based on long-term average runoff) as being "water stressed" and those have the per capita water availability below 1000 m3 per year as "water scarce". Under this definition, the World Bank (2005, 2006) indicates that Pakistan has already fallen below the water stress threshold and may reach a condition of water scarcity by 2035.

However, the World Bank estimates are based on a high value of available water supplies (perhaps including groundwater) and a lower population count (UN, 2008). Therefore, the current and projected water scenario could be more severe.

2.3 Historical Land Use and Land Cover Changes in the UIB and its Implication on Water Resources (Including Irrigation)

The environmental scenario of the Upper Indus basins has undergone tremendous environmental and socio-economic transformations over the last 5 to 6 decades. In this subsection, we showcase the historical land use and land cover changes observed since 1972, in the Jhelum basin of Upper Indus basin, that encompasses the entire Kashmir valley spread over an area of about 15, 500 sq.km. Over these decades, landscape in the Jhelum basin has been largely transformed and land is being converted for other uses without any regard for its congenital land use suitability. It has been reported that between 1952 and 1988, twelve hundred thousand hectares of forest area was lost (Romshoo et al., 1995). Increased population has also put pressure on the arable agricultural land for settlements. With changing hydrological patterns, a change in the cultivation patterns is being observed with a shift from agricultural to horticultural processes. Large-scale deforestation, dwindling grasslands, depleting water bodies and denuded landscapes have transformed the land surface processes linked to hydrology, erosion and climate/weather patterns in the Jhelum basin that are manifest by decreasing stream flows, increasing sediment and nutrient load (Romshoo and Muslim, 2011 and Romshoo and Rashid, 2012), shrinking fish habitat and degrading water quality (Rashid and Romshoo, 2012). The changes in the land system in the UIB from 1972-2008, shown in table 2.1 and Fig 2.7, Fig. 2.8 and Fig. 2.9, covering main land use and land cover cases are briefly discussed hereunder:

Forest: In the UIB, the forest area was 485473.31 ha in 1972 (36.89%), which shrunk to 464798 ha in 1992(35.16%), showing a decrease of about 20674 ha (1.73%) since 1972. The forest cover in 2008 was 391368 ha which is 29.6% of the total area showing a decrease of about of 6% from since 1992. The main cause of deforestation in the area is the increased need for timber, firewood, and the increasing population.

Agriculture: The total area under agriculture in 1972, as determined from the satellite data, was 337788 ha (25.56%), and in 1992 it decreased to 301094 ha (22.78% of the total area) showing a decrease of 36694 ha (2.78%) from 1972. The total area under agriculture in 2008 was 269139 ha (20.36% of the total area) showing a decrease of about of 31955 ha (2.5%) from 1992. The decreasing trends in agriculture are attributed to urbanization, increasing population, horticulture promotion and in some areas declining streamflows.

Horticulture: These are the area referring to cultivation of fruits like apples, pears etc. The total land under horticutlure in 1972 was 17954 ha as mapped from the satellite data. The total area under this category increased to 28858 ha in 1992 which accounts for 2.18%. The total area under horticulture rose to 71899 ha in 2008 accounting for about 5.44% of the total geographical. So there is an increase of 43040.9 ha. The large increase in the areas under horticulture is mainly attributed to the economic reasons as the fruti crops bring more economic benefits and in some areas this increase in horticulture is attributed to the declining streamflows and

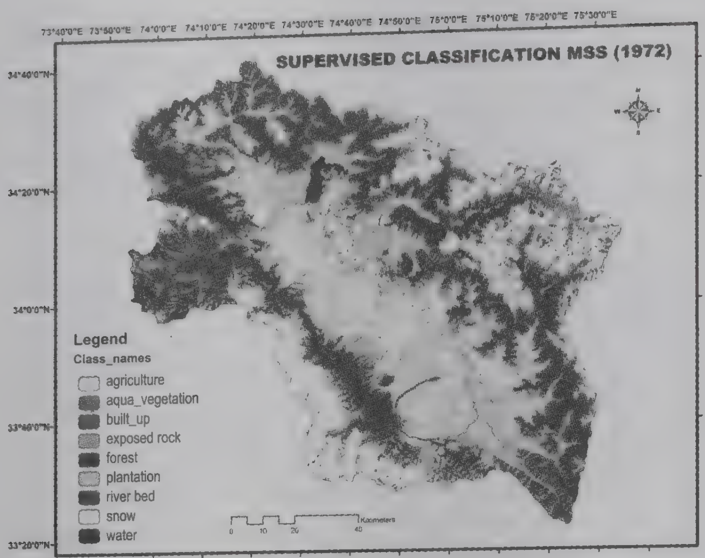

Figure 2.7: Showing the land use and land cover of Jhelum basin in 1972

thus reduced available water supplies for the water intensive agriculture like paddy cultivation.

River Bed: The total land area under the river bed was 9900 ha (0.74%) and 9812 ha (0.73%) in 1972 and 1992

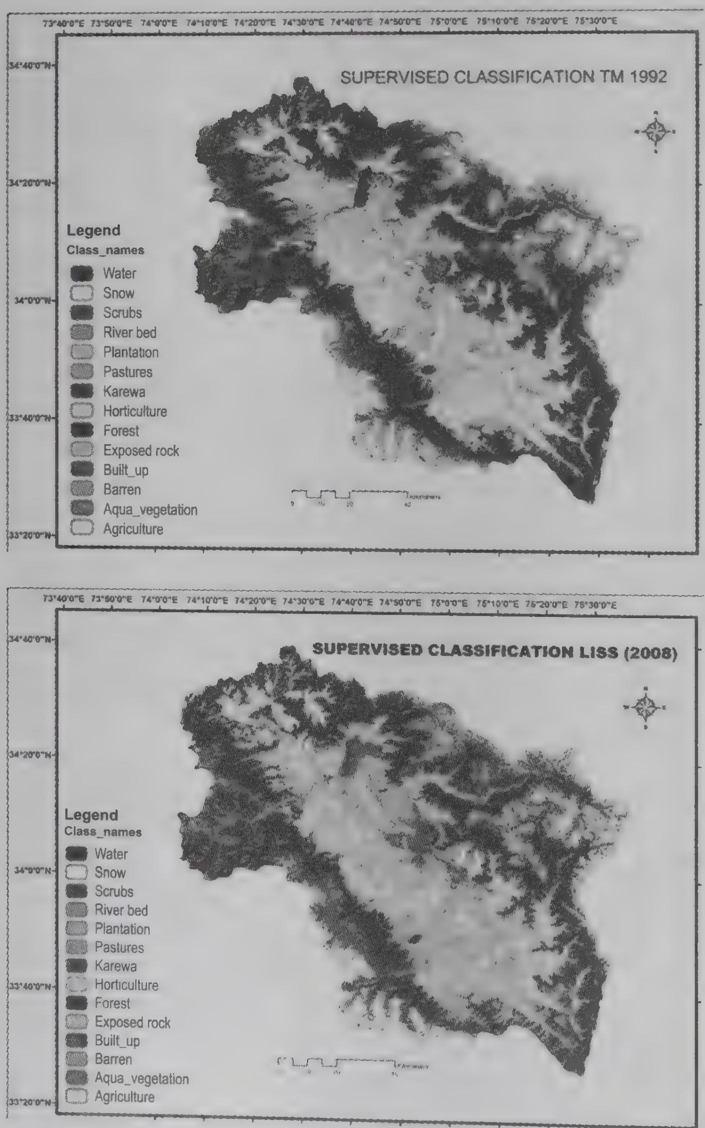

Figure 2.8: Showing the land use and land cover of Jhelum basin in 1992 and 2008

respectively. In 2008, the total area under rivers decreased to 7512 ha, covering an area equal to 0.56% of the total geographic area. This class shows a decrease of 2388 ha since 1972. This decreasing trend is because of the drying up of the seasonal nallahs and its conversion to built-up. Also, a part of this land has also been converted to the fruit crops through horticulture expansion.

CLASS NAME	1972 AREA (HA)	1992 AREA (HA)	2008AREA (HA)
FOREST	485473.31	464798.36	391368.55
AGRICULTURE	337788.45	301094.00	269138.93
PLANTATION	92240.15	89443.34	85876.76
HORTICULTURE	17954.44	28858.26	71899.18
WATER	12795.11	11024.42	6827.09
RIVER BED	9899.81	9812.22	7512.82
AQUATIC VEGETATION	3981.44	7503.56	11729.20
BUILT-UP	578.07	5914.96	21432.81

Table 2.1: Showing the land use and land cover change of Jhelum basin from 1972-2008

Open Waters: The area under open water (river channels, lakes, water bodies, canals, ponds etc) was 12795 ha (0.96%) in 1972 which shrunk to 11024.42 ha (0.83%) in 1992. The area under open waters further shrunk to 6827 ha (0.52%)in 2008 showing a decrease of 5968 ha since 1972. The decrease in the open waters is attributed to the drying up of the river beds, colonization of the water bodies by aquatic vegetation due to the influx of heavy nutrient loads from the catchment.

Built-up: The total land area under buil-up category has increase from mere 578 hectares in 1972 to 5914 ha in 1992. The build up area rose to 21433 ha in 2008 covering 1.62 % of the total geogrpahical area in the Jhelum basin. The increase in the built up area is attributed to the population increase from about 2.1 million in 1901 to 12.5 million in 2011.

Plantation: The total area under plantations cover and use in the Jhelum basin 92240 ha (6.97%) in 1972 that shrunk to 89443 ha (6.76%) in 1992. The area under horticulture further declined to 85877 ha (6.49%) in 2008. This decrease of 6363 ha (0.21%) from 1972 to 2008 is because of conversion of plantated lands to built up in the vicinity of urban centres and partly to horticulture in the rural landscape.

Aquatic vegetation: Because of the presence of a large number of water bodies and wetlands in the Jhelum basin, there are extensive patches of aquatic vegetation colonizing these water bodies. The area covered by the aquatic vegetation was 3981 ha in 1972 (0.30%) which increased to 7504 ha (0.56%) in 1992. The area under this land cover rose to 11729

ha (0.88%) in 2008, showing an increase of 7748 ha since 1972. The sharp increase in the land under aquatic vegetation is attributed to the eutrophication of the water bodies in basin due to the heavy influx of nutrient load from the catchments where there people resort to reckless use of pesticides for agriculture and horticulture lands.

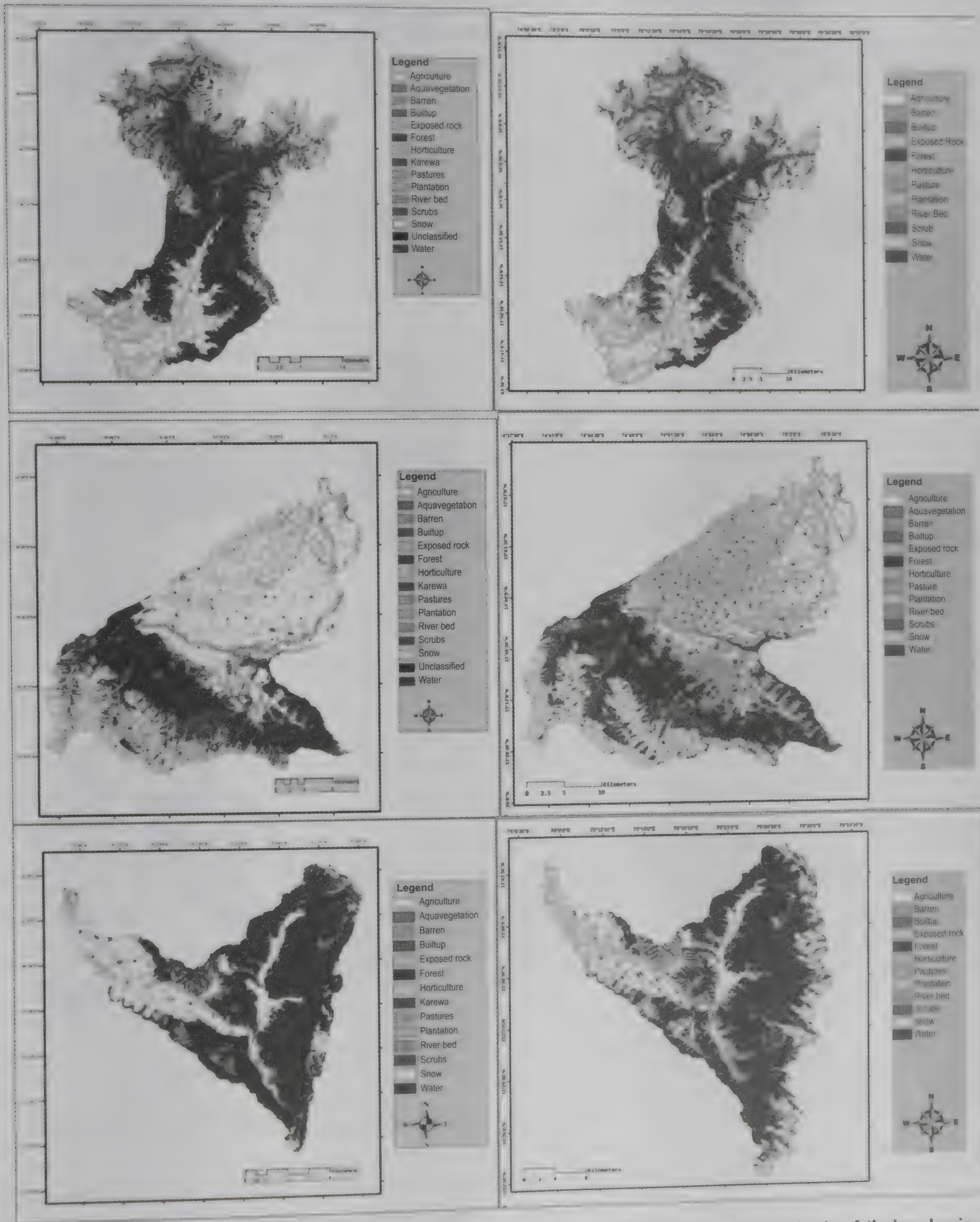

Figure 2.9: Showing the land use and land cover at watershed level in few of the watersheds of Jhelum basin (1972-2008)

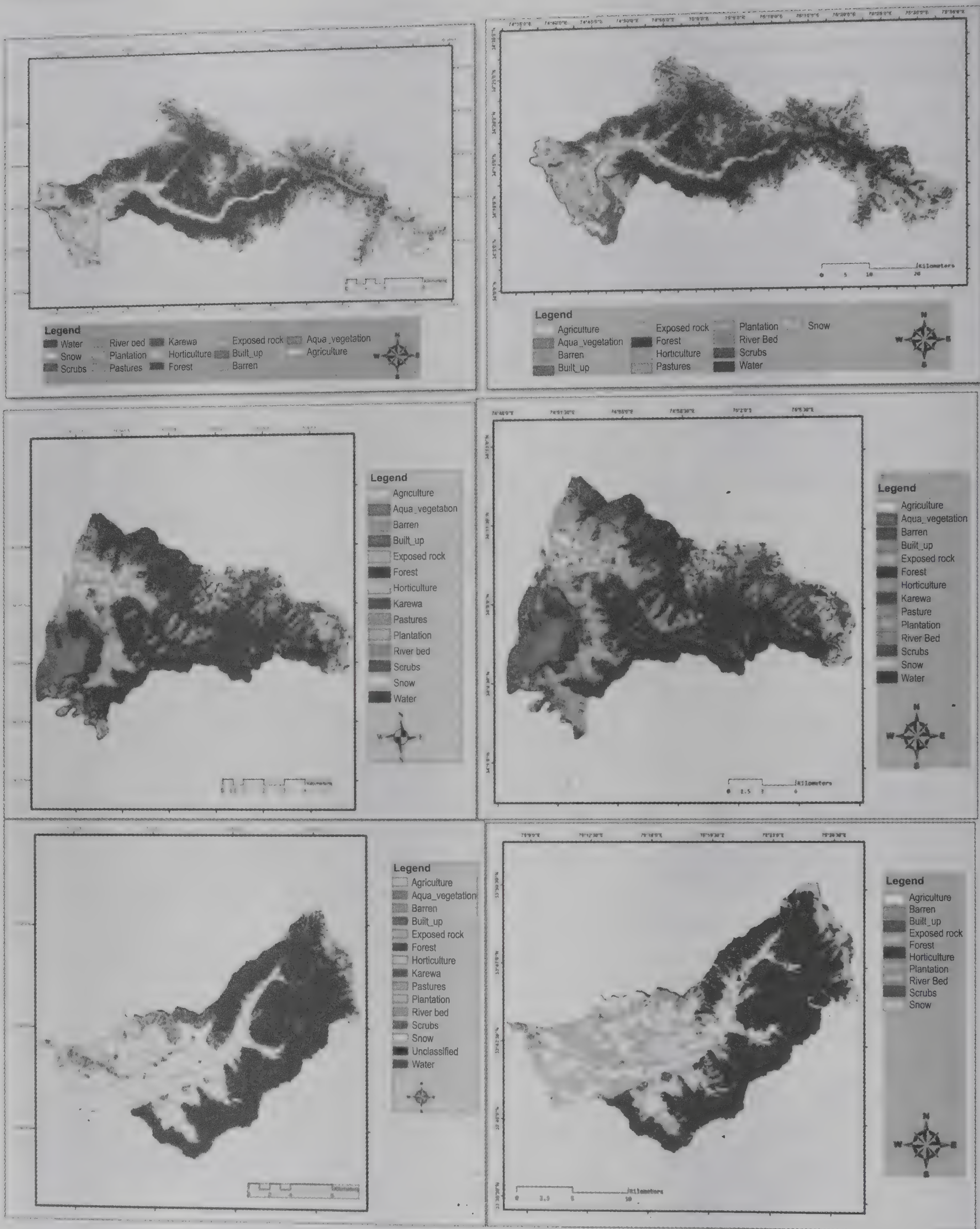

Figure 2.10: Showing the land use and land cover at watershed level in few of the watersheds of Jhelum basin (1972-2008)

The land system changes in the Upper Indus Basin (UIB) observed and detailed above have serious implications for the catchment scale hydrological processes, not in the basin but also in the downstream part of the Indus. Extensive deforestation of natural forests in the upland catchment area for timber and fuel wood reduces the water-retention capacity of the forest eco-systems. The rapid expansion of human settlements together with the construction of hydroelectric dams, barrages and an extensive

system of roads, railways, bridges, flood protection embankments and drainage channels all serve to divert or constrain the natural pathways of rivers and its tributaries. These land system changes and accompanying degradation of the natural environment in the UIB since last few decades has affected the streamflows, surface runoff, sediment yields and water quality of the river system. As could be noticed from the above analysis, the area under water intensive paddy cultivation has decreased substantially by about 68800 ha during the last about 40 years only and the same has been either transformed into horticulture or built up land. This has significantly reduced the demand for irrigation of the agriculture lands in the UIB

However, the scenario in the Lower Indus Basin (LIB) is different where the lands under agriculture are consistently increasing to meet the food requirement of the increasing population. Officially five million acre riverine cultivation is reported in the Pakistan (WAPDA 2000). The water used by riverine agriculture is around 20 MAF (Habib 2004). The total surface water availability in the Indus Basin is 137× 109 m3 with a total served area of 16.7 million ha (Bhutta and Smedema 2007), which implies, on average, about 820 mm of surface water is available for each irrigated hectare. Because of economic pressures and modernisation, the cropping intensities are increasing with future demand further increasing. Irrigated agriculture currently accounts for more than 90% of blue water requirements in the Indus basin, mainly Pakistan. Water from the sparsely inhabited mountainous UIB is essential for the densely populated semi- to hyper-arid lowlands with its extensive irrigation system. Agricultural sector use has reached 70 per cent of the river inflow, more than 95 per cent of the developed water and more than 90 per cent of the groundwater pumped. During a dry year, the percentage of river water used goes to 90 per cent (PWP 2000). Irrigated lands supply more than 90% of the total agricultural production and are major user of the water resources in Pakistan (Qureshi et al. 2009). Figure 2.9 and 2.10 show the land use and land cover changes at watershed scale that have occurred in the Jhelum basin from 1972-2008.

2.4 Technical and managerial factors affecting trans-boundary sharing of Indus waters

The transboundary distribution and use of a resource as a potential contributor to conflict has been the subject of considerable research, and has dominated the post-cold war interest in environmental security (Khagram and Ali, 2006). Within this genre much attention has been given to water resources, owing to their vital importance for human survival. The distribution of environmental resources may contribute to conflict, but recently the nation states have begun to focus on addressing the potential of environmental threats in stimulating conflict resolution (Ali, 2003; 2007). Environmental cooperation may offer pathways to confidence-building or peace building, whether or not the conflict has environmental roots or not. Despite inveterate antagonism between India and Pakistan, the two countries have began to initiate discussions on how to cooperate over water resources of the Indus River (Ali, 2008).

The Indus Waters Treaty represents the only on-going agreement between India and Pakistan that has not been disrupted by wars or periods of high tension. The treaty is often cited as a success story of international riparian engagement, as it has withstood major wars between the two signatories, several skirmishes over water distribution and derivative territorial concerns (Salman and Uprety, 2002).The irony is that despite the many wars that India and Pakistan have fought over a variety of issues, water is the one area where the two countries had found accommodation through the Indus Water Treaty (Mattoo, 2010). He says that the challenge for the two governments, therefore, is to ensure that cooperation in this respect is not derailed. Rebuilding trust over the sharing of the Indus waters could even become the precursor for generating trust in other areas of conflict. Although the treaty is admired for withstanding wars and conflicts between the two countries, it has not been able to play any role in forestalling war.

The mechanics of the treaty has survived so far, but the treaty itself has not been able to be part of a solution to animosities. This is because the institutions, which deal with water and environment, do not work in tandem with the national security agencies (Hasnie, 2010). In fact, the water resources management discourse on the Indus is being securitized as national security concerns are being linked to the management of Indus waters. This securitization of the Indus discourse is contributing to retarding institutional development and is undermining the extent to which uncontested hydrological data can be generated and shared between the two countries (ORF-LUMS, 2011). This is setting off a spiral of discontent and mistrust between the two countries. However, there have been several initiatives under Track-II to make the two countries synergize their concerns on the sharing of Indus waters without the securitization of the discourse. Therefore, there is a hope that the cooperation that builds on this treaty could not only present opportunities for better water management between those two countries, but also serve as a model for water-sharing arrangements between India, Bangladesh and Nepal (Siddiqui, 2004).

However, despite the above proclamations by the two sides, the Treaty is not entirely effective and faces difficulties in implementation to the dissatisfaction of both the parties, particularly Pakistan, as it does not provide mutually acceptable solutions to the complicated emerging issues. In fact, there is

no mechanism within the existing Treaty to address several of the emerging concerns on the use and sharing of Indus waters. An array of the upcoming Indian hydropower projects in the UIB has also unfolded many challenges to the functioning of the Treaty. The treaty is unable to cope with the issues which were originally not within its purview as they did not exist at that time (Briscoe, 2010). Taking a cue from the Baglihar verdict of the Neutral Expert that reinterpreted the Treaty in the light of "new technical norms and new standards," "state of the art" and "best and latest practices in the field of construction and operation," the risks of increased floods associated with "climate change,' it appears that the Treaty has to accommodate the new realities in the Indus basin, not only in terms of technical norms but also growing pressures on the health and viability of the Indus basin rivers. If climate change is to lead to a période of frequent floods, it will also be followed by a period of shortfalls in water flows. This demands a common water vision by India and Pakistan that will be based on realization of the importance of the shared rivers as being a natural resource that is integral to their survival. New and innovative areas of cooperation, inside and outside the Treaty, can be envisaged. With goodwill, there are multiple ways in which the treaty could be maintained but reinterpreted so that both countries could win (Briscoe, 2010). Briscoe says that discussions on the Indus waters should be de-linked from both historic grievances and from the other Kashmir-related issues. He said it is a sign of statesmanship, not weakness, to acknowledge the past and then move beyond it.

Mattoo, 2010 said that while the Indus Water Treaty is still a vital document, it may be important to think of ways of harnessing the waters of the Indus Basin jointly for more optimal use of the resources, given new technology, better practices, greater scarcity, and lessons learnt from the past. These could be included though an additional protocol to the treaty. The future cooperation on the Indus Water Treaty should include watershed management of the catchment areas of the Indus river system, especially the upper catchment areas of the Western rivers. "Water should be an instrument of peace - a means to achieve human security rather than a source of discord," (WWC, 2009).

Pakistan has time and again complained that India is not providing the information it is bound to supply under the treaty; be it the exchange of hydro-meteorological data or the timely and detailed information on the proposed hydropower projects. Pakistani officials say that India had not yet responded to technical concerns over different projects, which India was building on "Pakistani" rivers. The alleged delay on part of the India has often lead to the mistrust and antagonism, claims most of the Pakistani establishment. They argue that the decision to seek international arbitration in the case of Baghliar has been taken after considerable delay to give the bilateral dispute-resolution mechanism a chance. The issue has been on the agenda of the Permanent Indus Commission for eight years. There are allegations from Pakistan that India has not been forthcoming in sharing information and engineering details regarding various pipeline hydropower projects as required in the Treaty has aroused Pakistan's apprehension (Shaheen, 2010). Shaheen further wrote that these proposed projects are not merely run-of-the-river structures as allowed under the treaty but that their number and structures will allow India to acquire manipulative control that could be used to hamper water flows into Pakistan.

However, Briscoe, 2010 says that the reality is that India could tap virtually all of the available power without negatively affecting the timing of flows to which Pakistan is entitled. He contends that since the use of hydropower will not affect either the quantity of water reaching Pakistan or to interfere with the natural timing of those flows as the hydropower generation does not consume water, the only issue is timing. And timing is a very big issue, because agriculture in the Pakistani plains depends not only on how much water comes, but that it comes in critical periods during the planting season. Briscoe says that while the Neutral Expert's finding was reasonable in the case of Baglihar, it left Pakistan without the mechanism (limited live storage), which was its only protection against the possible upstream manipulation of flows in India. This vulnerability was driven home when India chose to fill Baglihar exactly at the time when it would impose maximum harm on farmers in downstream Pakistan. The Pakistani stakeholders quite often quote, as an example, the episode over the filling of the Baglihar water reservoir by India and the alleged "delayed" release of water has been cited as an example of India's mala fide intentions.

For Pakistan Indus water is the only lifeline for its survival; its existence depends upon the implementation of the Indus Water Treaty, not according to the letter but according to its real spirit. Obviously, Pakistan would like this treaty to address all possible hindrances and potential manipulations in terms of quantity and timing of all allocated flows from the three western rivers to its territory (Khan, 2010). Being in the driving seat, India should show generosity expected from an emerging great power as it has all levers of control to avoid a train-wreck on the Indus says Briscoe (2010)

2.5 Depletion of Groundwater resources in the Indus basin:

Groundwater has emerged as an exceedingly important water resource and its increasing demand in agriculture, domestic and

industrial uses ranks it as a resource of strategic importance. Global estimates show that approximately 4,430 km3 of fresh water resources are abstracted annually, of which 70% are used in agriculture, 25% in industry and 5% in household (Kinzelbach et al. 2003). On the whole, annual groundwater abstracted for the world can be placed at 750–800 km3, which is about one-sixth of the total freshwater abstraction (Shah 2000). The groundwater aquifer in the sweet zone of the Indus Basin is a reliable and rechargeable secondary source. It has played a major role in providing extended water access outside the canal irrigated areas in the basin. Fresh shallow groundwater has been used for centuries for domestic and animal consumption, but the last two decades have seen the extensive development of shallow tube wells operated by electric, diesel, or mechanical power. The use of groundwater has become a critical factor in all water use sectors in the basin. However, the current rates of exploitation are unsustainable in many regions of the basin. Falling water tables and increasing salt contents in the pumped groundwater attest that, in future, groundwater will become more expensive and inferior in quality, which will have serious consequences for Pakistan's capacity to feed its growing population (Qureshi et al. 2009). Pakistan has a shortage of water in all areas, with higher vulnerability in the saline and more arid areas. The agriculture of the Lower Indus traditionally depended on the surface storage, but its depletion in recent years has forced the farming community to supplement the irrigation requirement from the groundwater. More than 0.6 million tube wells (NESPAK, 1991) are operating in the Indus Basin. Groundwater pumpage is most beneficial in the non-perennial canal-irrigated agricultural areas. Currently, groundwater contributes 35 per cent of the total water available to users in Pakistan.

In major part of the Indian Punjab state, ground water levels are in the range of 10 to 20 metres. However, around major cities like Jalandhar, Ludhiana, Patiala, Amritsar and Sangrur, water levels are 20 to 40 metres deep (Gupta, 2005). The long- term water level fluctuation data indicates that water levels in major parts of the state have declined drastically. Quaternary alluvial deposits of Indus river basin cover Punjab and these alluvial formations are important sources of abundant and dependable ground water supplies. Because of large saturated thickness and high well yields, alluvial formations in Indian Punjab have been extensively exploited for large-scale supplies of water for industrial, irrigation and urban use. Despite the fact that Punjab occupies only 1.57% geographical area of India, it contributes more than 50 % grain in the central grain pool. More than 83% of land in Punjab is under agriculture as compared to 40.38% of national average. The cropping pattern of wheat and paddy rotation has led to manifold increase in irrigation water demand. Injudicious surface water irrigation policies, indiscriminate/excessive ground water pumpage due to free electricity coupled with irrational irrigation and agricultural practices, have led to a situation wherein fresh ground water resources of the Indian Punjab state have depleted at an alarming rate in most parts of the state (Gupta, 2005). As per the ground water assessment carried out, net dynamic ground water resources of Punjab State are 21.443 MCM (million cubic metres), whereas net draft is 31.162 MCM, leading to ground water deficit of 9.719 MCM (Gupta, 2005). The stage of ground water development for the State as a whole is 145% and the State falls in the "over-exploited" category. In Pakistan, one estimate roughly puts the groundwater pumpage at 40 MAF (WAPDA, 2001), which is also a source of drinkable groundwater for more than 70 per cent population of the country.

Due to the profitability and availability of water at shallow depths during the 1970s, paddy and wheat (two of the high water-consuming crops) replaced other less-water-intensive crops like maize, groundnut and pulses in the entire state of Indian Punjab. The area under these two crops increased from 7.22 per cent to 32.92 per cent for paddy and from 37.12 per cent to 43.53 per cent for wheat, from 1965 to 2005 (Jeevandas et al., 2008). Consequently, the problem of groundwater depletion has become severe in some areas of Indian Punjab, with a fall of 77cm/ annum in water table reported in Amritsar, Indian Punjab.

However, the current groundwater exploitation rates are unsustainable in several regions of, both, UIB and LIB. There is a large imbalance between extraction and replenishment. Water tables are falling at alarming rates, both on the Pakistani (Qureshi et al., 2009; Tiwari et al., 2009) and Indian sides (Rodell et al., 2009; Sundarajan et al., 2008; Tiwari et al., 2009). For the Indus basin, Tiwari et al. (2009) estimated a change (loss) of terrestrial water storage of about 10 $km^3\ yr^{-1}$ between April 2002 and June 2008. Excessive lowering of the groundwater table has made pumping more expensive. As a result, many wells have gone out of production, yet the water table continues to decline and salinity increases in the basin. Observations from the NASA Gravity Recovery and Climate Experiment satellites and simulated soil-water variations from a data-integrating hydrological modeling system show that groundwater is depleting at a mean rate of 4.0 + 1.0 cm yr^{1} equivalent height of water (17.7 + 4.5 $km^3\ yr^{1}$) over the Indian states of Punjab and Haryana. During the study period of August 2002 to October 2008, groundwater depletion was equivalent to a net loss of 109 km^3 of water, which is double the capacity of India's largest surface-water reservoir (Rodell et al., 2010). Although the observational record is brief, the available evidence suggests that unsustainable consumption

of groundwater for irrigation and other anthropogenic uses is the likely cause.

The present uncontrolled and unregulated use of groundwater is replete with serious consequences. In the business-as-usual scenario, problems of groundwater overexploitation will only become more acute, widespread, serious and visible in the years to come. If sound measures are not taken soon to ensure sustainable groundwater usage in the basin, the consequences for the residents of the region may include a reduction of agricultural output and shortages of potable water, leading to extensive socio-economic stresses. Rapidly falling groundwater tables and increasing salt content in the pumped groundwater in the basin and in particular in Pakistan are threatening the sustainability of irrigated agriculture. The frontline challenge is not just supply-side innovations but to put into operation a range of corrective mechanisms before the problem becomes insolvable (Quereshi et al., 2008). However, the control of groundwater pumpage is a difficult problem to be addressed, because it has become a major source of water supply for domestic and industrial uses, irrigation and food production in both the countries. The conjunctive use of surface and groundwater by farmers should be encouraged to minimize the problem of groundwater depletion in both the countries (Qureshi et al., 2009).

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CHAPTER III

New, Emerging and Anticipated Concerns

Summary: *This chapter discusses the new and emerging concerns on water sharing between the two countries. We have organized the material and discussion in this chapter into the following specific topics:-*

a) Climate change impact on the various water sources

b) Impact of proposed hydroelectric projects on water sources

c) Any other concerns about water by any of the stakeholders

Under each of these topics, we have briefly discussed the international scenario and tried to link this up with the available literature and indices in the Upper Indus Basin. For example, for climate change, there is plethora of information available on the impact of climate change on the water resources at the global level. We have showcased how the climate change is impacting the cryosphere, stream flows, food security and other sectors in both the Upper Indus Basin (UIB) and the Lower Indus Basin (LIB). Similarly, we have briefly discussed the impact of the proposed cascade hydropower projects on the availability of water resources in the long run and on different aspects of the environment mostly taken from the case studies conducted elsewhere. A few of the emerging and futuristic concerns on the availability and use of water resources in the basin, as expressed by various stakeholders in the basin, are also discussed in this chapter.

The best way to deal with the Indus water issues is to jointly look into problems of entire Indus basin, which could materialize only if there is a political will on both the sides. The collaborative understanding of the system may, in due course of time, when the political relations between the two countries improve, finally lead to the joint management of the basin.

3.1 Climate Change Impact on Various Water Resources

a) Climate change Scenario: International and Regional

Instrumental records show a systematic increase in global mean temperature (Folland et al. 2001a, b), with global mean temperature increasing at a rate of 0.07°C decade-1over the last century (Jones and Moberg, 2003). In addition, the 1990s were the warmest decade, and 1998 the warmest year since the start of the global mean temperature record in 1856 (Jones and Moberg 2003). However, the warming has not been globally uniform. High northern latitudes have been particularly affected, with reconstructions of mean surface temperature over the past two millennia suggesting that the late twentieth century warmth is unprecedented (Mann and Jones 2003). This has been attributed to the anthropogenic forcing of climate (Thorne et al. 2005). In most parts of the world, there have been differential changes in daily maximum and minimum temperatures, resulting in both a narrowing of Diurnal Temperature Range (DTR) and an increase in mean temperature (Karl et al. 1993; Easterling et al. 1997; Jones et al. 1999). However, there are suggestions that the western Himalaya region is showing a different response to global warming (Kumar et al. 1994; Yadav et al. 2004), with an increased DTR and more cooling of mean temperature in some seasons, possibly as a result of local forcing factors.

Regarding the concerns about the impact of climate change on the Indus, based on an assessment of given temperature changes in line with global climate change projections (Rees and Collins, 2006; Akhtar et al., 2008), expectations of dramatic decreases in river flow have arisen (World Bank, 2005). Reports of significant retreat and depletion of glacier

volume across the Hindu Kush Himalayas (HKH), such as in the eastern and central Himalaya (Hasnain, 1999; Shrestha et al., 2004) have supported these concerns. However, the effects of climate change on glaciers and on river flow in the western HKH are not yet clear (Archer et al. 2010). Fowler and Archer (2005) have shown that although mean annual temperatures are generally rising in line with the global average, summer temperatures (July to September), the key for glacial melt, have been falling at many valley stations in the Karakoram during the period 1961 to 2000. Hussain et al. (2005) showed similar temperature falls in both the monsoon and pre-monsoon (April–May) period for the high mountain region in the Central Himalayas. In addition, Archer and Fowler (2004) indicated that there have been significant increases in precipitation in the Upper Indus in both winter and summer in the period 1961 to 1999.

Fowler and Archer (2005) analyzed the temperature data for seven instrumental records in the Karakoram and Hindu Kush Mountains of the Upper Indus Basin (UIB) for seasonal and annual trends over the period 1961–2000 and compared the results with the neighbouring mountainous regions and the Indian subcontinent. They found strong contrasts between the behaviour of winter and summer temperatures and between maximum and minimum temperatures. Winter mean and maximum temperature were found to show significant increases while mean and minimum summer temperatures showed consistent decline. The impact of observed seasonal temperature trends on runoff revealed a decrease of 20% in the summer runoff in the rivers of Hunza and Shyok attributed mainly to the observed 1°C fall in mean summer temperature since 1961. Even greater reductions in the temperatures of spring months have been reported in the literature (Fowler and Archer, 2005).

Various studies have reported differing findings on temperature trends in the region and the basin (Bhutiyani et al., 2009). Although, Fowler and Archer (2006) have shown that mean and minimum summer temperatures provide a consistent trend of cooling beginning in the year 1961, Chaudhry and Rasul (2007) have pointed out a non-significant increasing trend for annual mean temperature in the mountainous areas of the Upper Indus Basin in Pakistan. In contrast, in the Baluchistan, Punjab, and Sindh provinces in the Lower Indus Basin (LIB), a significant trend of increasing annual temperature was observed for the period from 1960 to 2007, amounting to a total of +1.15°C in Baluchistan, +0.56 °C in Punjab, and +0.44°C in Sindh during the 47-years period. However, a seasonal trend in the Upper Indus Basin is visible in the form of rising summer and falling winter temperatures. However, there is evidence that historic climatic trends in the UIB have not fallen in line with global trends with respect to seasonal trends in temperature (Fowler and Archer, 2006) or precipitation (Archer and Fowler, 2004). Sheikh et al. (2009) have provided an assessment for the whole of Pakistan of changes in climatic variables, again showing significant departures from the global pattern. Analyses of the time series of the available temperature data since 19th century shows significant increasing trend in the annual temperature for all the three stations analysed in the North-western Himalayan region (Bhutiyani et al.2009). Klein Tank et al (2006) have reported similar research findings from the region.

Bhutiyani (1999) used the hydrological (water-balance) method to compute the mass balance of the Siachen glacier in the Nubra Valley, eastern Karakoram range, India, the largest glacier in the Himalayas from 1986-1991. The average mass-balance was found to be negative with the lowest being in 1990-91 (-1.08 m). A positive mass balance was calculated for 1988- 89 (+ 0.35 m) that was attributed to comparatively heavy winter snowfall amounts and low temperatures during the ablation season. Significantly lower runoff was measured during this season. It was reported that most of the negative values of 1989-1990 and 1990-1991 were the result of comparatively dry winters and warm ablation periods, with monthly mean air temperatures 1.4 to 5.1°C higher at the beginning of the ablation season, June and July, than the mean of the preceding five years.

Fowler and Archer (2005) while assessing the hydro-climatological variability in the Upper Indus Basin and its implications for water resources observed that most flow in the upper Indus is derived from melting snow and glaciers. The authors reported that summer runoff is strongly correlated to winter precipitation and summer temperature, though links may operate in opposing directions in glacier-fed and snow-fed hydrological regimes. From 1961 to 1999 there were significant increases in winter, summer and annual precipitation and significant warming occurred in winter whilst summer showed a cooling trend. Based on three long-term (1894–1999) records at Gilgit, Skardu and Srinagar, the authors reported that there is no statistically significant trend in annual or seasonal precipitation over the last century. However, analysis of these and other records showed an evidence of an upward trend in winter precipitation across the region since 1961, showing statistical significance at Skardu and Dir, with increases of 18 and 16% per decade, respectively. Contrasting trends in annual mean temperature were observed in the UIB.

Long-term stations at Skardu and Srinagar showed a warming trend whilst Gilgit showed a cooling trend. These trends were observed to be intensified since 1961, as exemplified for Srinagar. Trends differed between seasons and between

mean daily maximum and minimum temperatures. The greatest warming rates were observed in winter, with warming since 1961 resulting primarily from the increase in winter maximum temperature. This increase was large and statistically significant at Gilgit, Skardu and Dir, with increase of 0.27, 0.55 and 0.51°C per decade, respectively. The authors reported a significant summer cooling since 1961, with negative trends in both minimum and maximum temperature. Reductions in summer minimum temperatures were statistically significant ranging from −0.4 to −1.11°C per decade. However, the cooling of maximum temperature was observed to be less significant and this response was observed to be shared with the neighbouring region of northwest India where Hingane et al. (1985) found a negative trend of −0.05°C per decade since 1901. The authors concluded that on the basis of the derived climate–runoff relationships, it is predicted that the observed decreasing trend in summer temperature will result in a seasonal decrease in runoff on predominantly glacier-fed catchments such as the River Hunza, but may increase runoff volume on snow-fed catchments due to decreased evaporative loss. Iram and Romshoo (2012) showed statistically significant decline in the stream flows from most of the major tributaries of the Jhelum in the UIB despite less demands for irrigation of the water demanding paddy culture that is on the decline. They attributed these reductions in the stream flows to scanty snowfall, increasing water demands for burgeoning populations and the reduced glacial mass in the basin.

In another study, Fowler and Archer (2006) analyzed temperature data for seven instrumental records in the Karakoram and Hindu Kush Mountains of the Upper Indus Basin (UIB) and annual trends over the period 1961–2000 were compared with neighboring mountain regions and the Indian subcontinent. Trends were analyzed for annual, seasonal, and monthly mean, maximum and minimum temperature at Dir, Drosh, Bunji, Gilgit, Astore, and Skardu stations from 1961–99. For Srinagar station, only mean temperature for the period 1961–2000 was available for investigation. The results revealed strong contrasts between the behavior of winter and summer temperatures and between maximum and minimum temperatures. Significant increases were observed for winter mean and maximum temperature, while a consistent decline was recorded for mean and minimum summer temperatures. The authors reported a consistent increase in diurnal temperature range (DTR) in all seasons and the annual dataset, a pattern shared by much of the Indian subcontinent but in direct contrast to both GCM projections and the narrowing of DTR seen worldwide. This divergence commenced around the middle of the twentieth century and is thought to result from changes in large-scale circulation patterns and feedback processes associated with the Indian monsoon. The impact of observed seasonal temperature trend on runoff was explored using derived regression relationships. Decreases of 20% in summer runoff in the rivers Hunza and Shyok are estimated to have resulted from the observed 1°C fall in mean summer temperature since 1961, with even greater reductions in spring months. The observed downward trend in summer temperature and runoff was consistent with the observed thickening and expansion of Karakoram glaciers, in contrast to widespread decay and retreat in the eastern Himalayas. The results of this study suggested that the western Himalayas are showing a different response to global warming than other parts of the globe.

In light of the scenario discussed above, the indicators of the climate change are quite clear and loud in the Indus Basin. The climate change is already impacting several sectors in the region and has adversely affected the cryosphere, hydrology, land system, forestry and even the livelihood of the communities inhabiting the upper and lower Indus basin. We now briefly discuss the impact of the climate change on various water resources.

b) Climate change Impacts on Glaciers

Climatic change and its impacts on the fluctuation of glaciers are a natural phenomenon that has been occurring throughout the five billion-years history of mother Earth (WWF, 2005). However, in the past few decades, global climate change has had a significant impact on the high mountain environment including snow, glaciers and permafrost that are particularly sensitive to the changes in the atmospheric conditions because of their being fragile. As a result, glacier recession observations have been used for climate system monitoring for many years (Haeberli, 1990; Wood, 1990). UNEP (2010) has listed the works of different researchers who state that recent satellite observations have confirmed that glaciers in many mountain regions are thinning (Berthier et al., 2007; Paul et al., 2007; Bolch et al., 2008a, b), conclusively showing that the majority of the glaciers in the mountainous regions are losing mass in response to climate change. According to the climatologists, alpine glaciers, such as those in the UIB of the Himalayas, are particularly sensitive indicators of climate change and the receding trend of these glaciers is expected to continue this century (Ageta & Kadota 1992; Nakawo et al. 1997; Hasnain 1999; Naito et al. 2000). Higher atmosphere temperature and the change of precipitation into liquid form at higher altitude in the Himalayas will lead to rapid retreat of glaciers and downstream flooding in the future (Hasnain 2002; Kadota et al. 1993).

Several research findings, all across the world, have demonstrated that the glacier cover in the mountainous regions

worldwide has decreased significantly in recent years as a result of warming trends (UNEP, 2010). A comparison of historical glacier data by the United States Geological Survey (USGS) has revealed a significant shrinkage of mountain glaciers in the Andes, the Himalayas, the Alps and the Pyrenees (Wessels et al. 2001). Dyurgerov and Meier (1997), who analyzed the mass balance changes of over 200 mountain glaciers globally, concluded that the reduction in global glacier area ranged from 6,000 km2and 8,000 km2 between 1961 and 1990. There are forecasts that up to a quarter of the global mountain glacier mass could disappear by 2050 and up to half could be lost by 2100 (Kuhn 1993a;Oerlemans 1994; IPCC 1996). As reported by UNEP (2010), in some regions, it is very likely that glaciers will largely disappear by the end of this century, whereas in other regions, glacier cover will persist but in a reduced form for many centuries ahead (Kulkarni et al., 2007; Ye et al., 2008; Bhambri et al., 2009; Nicholson et al, 2009; Wang et al., 2009; Yang et al., 2009; Federiciet al., 2010; Kaser et al,2010; Peduzzi et al., 2010; Shahgedanova et al., 2010; and Shekhar et al., 2010).

As per the IPCC (2007a) report, the spatial variation in the observed and projected climate change has been predicted to be larger in mountain ranges and their downstream areas compared to the plains and coastal areas. It has been reported that the temperatures will increase more in high mountains than at low altitudes (Bradley et al. 2006) as the rate of warming in the lower troposphere increases with altitude. Besides, mountain areas exhibit a large spatial variation in climate zones due to large differences in altitude over small horizontal distances making them more vulnerable to climate change (Beniston et al. 1997). Glaciers in much of the High Asia appear to be declining, some at globally extreme rates (Ageta 2001; Oerlemans, 2001).

Retreat of glaciers gives a very clear indication of a global climate that has been warming since the Little Ice Age (LIA), that occurred from approximately 1650 to 1850 (Oerlemans 2005). Throughout the world, including the Himalayan region, evidence from the glacier moraines provides an idea of the last maximum extent of these glaciers during the LIA and validates the fact that the glaciers have been retreating globally since this period in response to a warmer climate (Armstrong, 2010). Zemp et al. (2008) reported that there is now clear evidence that the retreat of glaciers in many locations of the world has accelerated in recent decades. However, glacier systems at the highest elevations, for example, have not responded to recent climate warming in the same way as glaciers that extend to lower elevations, simply because glaciers at higher elevations remain below freezing during much of the year, even in the presence of a warmer climate.

However, the IPCC reports that glaciers in the Himalaya are receding faster than in any other part of the world and that the receding and thinning of Himalayan glaciers can be attributed primarily to the global warming resulting due to anthropogenic factors such as aerosols with black carbon and dust, deforestation, forest fires, human-induced pollution, and emission of greenhouse gases (IPCC 2007b; UNEP, 2009). The global land ice measurements from space (GLIMS) project also report a consistent decrease of glacier extent in the upper Indus basin in particular (Kargel et al. 2005). However, there is inadequate data available on cryosphere, climatology, hydro-meteorology and other related earth system processes that could help us conclude about the fate of Himalayan cryosphere with fair amount of confidence. The repository of paleo climate data at high-altitude in the form of tree rings, pollen, ice-cores, paleosols and even the historical satellite images may help researchers to understand the dynamics of cryosphere in the area.

Most of the Himalayan glaciers since the last ice age have shown a recession following the trend of glaciers worldwide (Barry, 2006) and have been found to be in a state of general retreat since 1850 (Mayewski & Jeschke, 1979). Recent publications have confirmed that, for many of these glaciers, the rate of retreat is accelerating (Bajracharya et al. 2008) though mostly focusing on the glacier snout fluctuation (Jangpang and Vohra 1962; Kurien and Munshi 1972; Srikanta and Pandhi, 1972; Vohra 1981). For example, the Siachen and Pindari Glaciers were reportedly retreating at a rate of 31.5m and 23.5m per year respectively (Vohra, 1981). The Gangotri Glacier retreated by 15m per year from 1935 to 1976 and 23m per year from 1985 to 2001 (Vohra 1981; Thakur et al. 1991; Hasnain et al. 2004). On an average, the Gangotri Glacier is retreating at a rate of 18m per year (Thakur et al. 1991).

Recently, the consequences of climate change for Himalayan glaciers have become a great concern. Upstream snow and ice reserves of the Himalayan river basins, important in sustaining seasonal water availability over the entire South Asia, are likely to be affected substantially by climate change, but to what extent are yet unclear (Immerzeel et al. 2010). It had been widely reported that the Indus basin is threatened with severe losses. However, emerging evidence suggests that such reports were, at best, exaggerated (Raina, 2009; Armstrong, 2010).

The perennial snow and ice cover of the trans-Himalayan upper Indus Basin is about 20,000 km2 and the greatest share is in the Karakoram Himalaya (Hewitt, 2011) that has an extensive formation of glaciers due to high altitudes (Young and Hewitt, 1990). Nearly 11.5% of the total area of the UIB is covered by perennial glacial ice including most of the largest valley glaciers, the largest area outside the polar and Greenland

regions (Hewitt, 2001; 2007). Precipitation in the form of snow contributes the large moisture surplus for the UIB (Wake, 1989).While most of the world's mountain glaciers have been shrinking for at least the last 30 years (WGMS, 2002), including the neighbouring Greater Himalaya (Hasnain 1999; Mastny 2000), there is a disagreement among scientists whether all glaciers of the Himalaya–Karakoram–Hindu Kush region are retreating. The scientific literature is contradicting in this respect. Goudie et al. (1984) opined that the historical records of glacier fluctuations in the Himalaya and the Karakoram, indicate that, in the late 19th and early 20th centuries, the glaciers were generally advancing, followed by predominant retreat from 1910–1960. Karakoram glaciers have declined by 5% or more since the early 20th century, mainly between the 1920s and 1960s. However, losses slowed in the 1970s (Mayewski and Jensche, 1979), and some glaciers underwent modest advances, as elsewhere in the region (Kotlyakov, 1997). Fowler and Archer (2006) reported a thickening and expansion of Karakoram glaciers due to increased winter precipitation and decreasing summer temperatures. From the later part of 1990s, some findings about the glaciers stabilizing and, in the high Karakoram, even glacier advance have been reported (Hewitt 2005; Immerzeel et al., 2009).

The total snow cover has also reportedly been increasing in the high Karakoram (Naz et al., 2009). Immerzeel et al. (2010) also recorded a positive trend of snow and ice storage in the Indus basin. Hewitt (1998) reported widespread expansion of large glaciers in the central Karakorum, accompanied by an exceptional number of glacial surges. The author later in 2005 reported that central Karakoram is the largest of those very few areas where expansion of glaciers has been noted. Some of the largest glaciers in the Karakoram Range have undergone rapid thickening since the mid-1990s (Hewitt, 2005, 2007). This is contrary to most of the glaciers in the world reported to be shrinking for the last several decades, including the neighbouring Greater Himalaya analysed by Berthier et al. (2007). This contrast in glacier evolution shows a climate change pattern in Karakoram that differs from that in the Greater Himalaya (Fowler and Archer, 2005). ICIMOD reports that glaciers in the Hindu Kush-Himalayan Region are retreating at rates of 10 m to 60 m per year and many small glaciers (<0.2 sq.km) have already disappeared (Bajracharya et al. 2007).

Mayer et al. (2006) report that over the past 50 years the Baltoro glacier, located on the south side of the Karakoram and one of the largest in the Karakoram, and the world (approx. 1500 sq.km in area and more than 60 km in length) has apparently retreated only about 200 m. Mihalcea et al. (2006) carried out direct measurement of melt in the ablation zone of a Karakoram glacier. They measured melt on the Baltoro glacier using a network of ablation stakes along a transect from 4100 to 4800 m and estimated the equilibrium line altitude (ELA) for the Baltoro to be between 5300 m and 5500 m. The authors noted that above this elevation in almost all cases precipitation was deposited as snow, whereas, below this elevation, a significant portion of the surface area was debris-covered, increasing in thickness down glacier to reach a maximum exceeding 1 m near the terminus. This debris cover considerably reduces the rate of ice melt. The variation of ablation rate with changing debris thickness and local surface conditions was observed to be larger than the effect of elevation.

Rees and Collins (2006) applied a temperature-index-based hydro-glaciological model to determine by how much and when climate warming will reduce Himalayan glacier dimensions and affect downstream river flows. The authors located two hypothetical glaciers, of equal dimensions and initial geometries, within two hypothetical catchments representing the contrasting east and west climates of the Himalayan region. The model was applied from a start date of 1990 for 150 years with a uniform warming scenario of 0.06°C per year. It was observed that flows for these glaciered catchments attained peaks of 150% and 170% of initial flow at around 2050 and 2070 in the west and east respectively, before declining until the respective hypothetical glaciers disappear in 2086 and 2109. The study demonstrated that general modeling approach is appropriate here but model inputs and glacier geometries are hypothetical, and it is assumed that melt is uniform over the total glacier surface with no distinction between specific ablation and accumulation zones. Therefore, the accuracy of results is uncertain.

Since individual glaciers can respond with great variability to a changing climate, therefore, it is important to involve more regional-scale estimates in the analysis of Himalayan glacier mass balance. In light of this fact, Berthier et al. (2007) compared elevation data from 2000 Shuttle Radar Topography Mission (SRTM) data with a 2004 digital elevation model (DEM) derived from SPOT5 (Satellite Pour l'Observation de la Terre) imagery in the Himachal Pradesh region of northwest India. The results indicated an average mass balance of - 0.7 to - 0.85 m per year of water equivalent over a total glacier area of 915 sq. km which were comparable to the global average (Zemp et al. 2008).

In another study, Ren et al. (2007) applied three GCMs (global circulation models), with warming effects based on a high emissions scenario, over the 30-year period of 2001–30, across the greater Himalayan region. Despite certain regional differences, all three GCMs indicated a spatially averaged glacier thickness reduction of approximately 2 m for the period

2001–30, but only for those areas located below an elevation of 4000 m.

Bajracharya et al. (2007) reported that the BadaShigri, ChhotaShigri, Miyar, Hamtah, NagpoTokpo, Triloknath and Sonapani Glaciers in the Chenab River Basin retreated at a rate of 6.8 to 29.8m per year. The highest and lowest retreat rates were reported for the BadaShigri Glacier and ChhotaShigri Glacier respectively

A study carried out by Naz et al. (2008) in the Upper Indus Basin of the Western Karakoram demonstrated recent thickness changes on glaciers for the period 2004 to 2008 indicated the average thickness change over glaciers in the Hunza Valley to be approximately + 0.10 m/year in the ablation zone and approximately + 0.64 m/year in the accumulation zone, implying a recent mass balance regime that is positive.

Response times for the majority of Himalayan glaciers are most likely decades to centuries, appropriate for glaciers whose movement results mainly from internal ice deformation. Length changes of such glaciers, especially if debris-covered, cannot, therefore, be used as indicators of recent (decadal) climate change. Such decadal changes are much better reflected by smaller/steeper glaciers. Response time scales have been described by Raper and Braithwaite (2009), Adhikari et al. (2009), McClung and Armstrong (1994), and Johannesson et al. (1989).

Naz et al. (2010) reported that across the Upper Indus Basin in general, from 1977 to 2006, the snow covered area on the glaciers (accumulation zones) increased, while the ice-covered area (ablation zones) decreased, caused primarily by the increased snow area, but in particular locations by increased debris covered area, as well as simply due to localized glacier retreat. The authors indicated a pattern of decreasing equilibrium line altitude (ELA) and an associated positive glacier mass balance pattern over the study period. In addition, the authors ran a climate model (VIC) using daily maximum and minimum temperatures increased by 5°C (A2scenario) which led to a decrease in the seasonal snow cover at the lower elevations, but no comparable decrease at the elevations in the basins where the glaciers were located.

Scherler et al. (2010) reported terminus changes for more than 250 glaciers across the Himalayan region between 2000 and 2008 using satellite data. They noted that debris-free glaciers in regions of low relief have been mainly retreating, while debris-covered glaciers in high-relief areas (Karakoram glaciers) were mostly stagnating and in-situ down wasting, but not always retreating. The authors asserted from the results that regional differences in topographic relief and related debris cover should be considered when comparing glacier retreat rates.

As per ICIMOD (2010), temperature data from the Hindu Kush and Karakoram mountains of the Upper Indus Basin show a variable pattern that would support the stability, if not growth, of glaciers in the region. Since 1961, summer mean and minimum temperatures show a consistent decline while winter mean and maximum temperatures show significant increases, although still remaining well below the freezing level at the elevation of the glaciers (Fowler and Archer 2006).

As per ICIMOD (2010), glacier data in the Himalayas and surrounding mountains are very sparse, limited mostly to terminus location data that do not comprehensively describe overall conditions of the glaciers. Although more direct and comprehensive methods have been developed to determine the year-to-year condition of a total glacier system through mass balance measurements but being always complex and time consuming, only a few dozen such records in the world exist that cover significant periods of decadal time (Zemp et al. 2008, 2009). There are currently no such long-term records for the Himalayan region (Kaser et al. 2006).

Tahir et al. (2011) while assessing the snow cover dynamics and hydrological regime of the Hunza River basin also found a significant expansion of the snow cover area over an elevation of 4300 m. Hewitt (2005, 2007) stated that a unique climate regime in this area and exceptionally high-altitude ranges of the ice masses may be the important factors in this expansion, contrary to other regions. Probable reasons for this contrasting behaviour are attributed to possibly changing atmospheric circulation patterns; increased precipitation; a local trend of decreasing temperatures, particularly in summer (Fowler and Archer 2006; Tahir et al. 2011); or the influence of thick debris coverage, which protects the ice against melting (Hewitt, 2005; Hewitt, 2011). The impact of global warming is not effective because a large part of the basin area lies under high altitudes where the temperature remains negative throughout most of the year. Even if global warming is real, the mean temperature remains negative or very low over a large part of the basin area.

c) Climate Change impacts on the stream flows

As per Cruz et al. (2007) and Immerzeel (2009), snow and glacial melt form the major hydrologic processes in mountainous Himalayan regions where the changes in temperature and precipitation are expected to seriously affect the melt characteristics (Barnett et al. 2005). Although various earlier studies have addressed the importance of glacial and snow melt and the potential effects of climate change on downstream hydrology, but these are mostly qualitative (Barnett et al. 2005; Bates et al. 2008; Cyranoski, 2005) or local in

nature (Singh and Bengsston, 2005; Rees and Collins, 2006). The impact on river flows downstream depends crucially on the magnitude of other components of the hydrological cycle (e.g. rainfall, evaporation, groundwater flow), and thus varies greatly between regions (Immerzeel et al., 2010; Pellicciotti et al., 2010).

In the Indus basin, Karakoram, Himalaya and Hindu Kush Mountains form the major sources of the flow in the River Indus feeding the river by a combination of melt water from seasonal and permanent snow fields and glaciers, and direct runoff from rainfall both during the winter and the monsoon season from July to September. An understanding of the hydrological regimes of the mountains is critical for the management of the water resources in the basin and for protection against flooding (Archer 2002). The hydrological significance of glaciers in the Indus basin is very high (UNEP, 2007). About 40% of the melt water originates from glaciers in the Indus Basin (Immerzeel et al., 2010).The melt water component is extremely important and the primary source for irrigation of the entire Indus basin. Several authors (Hewitt et al., 1989; Wake, 1989; Young and Hewitt, 1988) reported that 80% of the flow of the Upper Indus River is contributed by less than 20 % of its area, essentially from the zones of heavy snowfall and glacierized basins above 3500 m in elevation. Liniger et al. (1998) stated that some 90% of the lowland flow of the Indus River System originates from the Hindukush, Karakoram and western Himalaya mountain areas. Winter precipitation provides the principal source for accumulation on UIB glaciers in the greatest area of perennial ice outside the Polar Regions (and upon melting, for runoff in the river Indus (Fowler and Archer 2005). In the UIB, summer runoff (July to September) is highly correlated with winter precipitation in middle-elevation basins dependent on an ephemeral snowpack (Fowler and Archer 2005). However, summer temperature and runoff are negatively correlated on these snow-fed catchments where increased temperature results in increased evaporative loss and, since snow cover volume is limiting, in reduced runoff (Singh and Bengtsson 2005). Decreases of approximately 20% in summer runoff of the Hunza and Shyok rivers are estimated to have resulted from the observed 1°C decrease in mean summer temperatures, a pattern consistent with the observed thickening and expansion of some Karakoram glaciers (Fowler and Archer 2006; Hewitt 2005).

As a result of the scarcity of long-time series' data for these mountainous systems, the analysis of trends in river flow moreover is limited by factors that render either generalizations or model-based predictions difficult (Singh et al. 2008; Sharma 1993). Rivers that are fed heavily by glacial melt water will respond differently to temperature rises than rivers which are mostly fed by rainwater during the monsoon (Singh et al. 2008). It was observed from analyzing the long-term data on the Hunza basin in the Karakoram region (sampled at the Dainyur bridge), runoff between 1980 and 2004 showed a slight negative trend (3 mm per year) and was attributed to an increase in the storage of snow and ice at higher altitudes (Khattak et al. 2011). The large rivers of Nepal exhibit no consistent trends; the Karnali and Saptakosi show a decreasing trend, whereas the Narayani shows an increasing trend, the southern rivers show no definite trend; and discharge in the snow fed rivers indicates a declining trend (Shrestha and Aryal, 2011).

Concerns about the potential impacts of climate change on flow in the Indus (Rees and Collins, 2006), given temperature changes in line with global climate change projections (Cruz et al., 2007), have given rise to expectations of dramatic decreases in magnitude of river flow (Briscoe and Qamar, 2005; Immerzeel et al., 2009). However, temporal trends in stream flow have received limited attention in the upper Indus. Khattak et al. (2011) assessed monthly trends at eight stations in the UIB and found predominantly increasing trends in winter and decreasing trends in summer. In contrast, temporal changes in the river flows in other regions such as the western United States have been extensively studied showing positive or negative effect on water resources.

The expectation of severely reduced resources expressed by Rees and Collins (2006) and the World Bank (2005) rests on two assumptions: that the effect of rising temperature on glacier melt is the primary impact on water resources; and that temperatures in the Upper Indus will rise in line with global climate change projections. However, both these assumptions are questionable. The area of seasonal snow is an order of magnitude greater than the area of perennial snow and ice, although the area diminishes and cover is depleted through the melt season. In this zone, including the greater part of the upper Jhelum basin (Archer and Fowler, 2008), winter precipitation and summer runoff is significantly positively correlated. In contrast to the glacial regime, summer runoff and summer temperature are uncorrelated or even negatively correlated. Hence trends in winter precipitation are likely to have the most significant impact on runoff.

Young and Hewitt (1988) while analyzing the discharge records from the principal gauging stations in the Upper Indus Basin observed that yield varies greatly between basins, from lows of near zero for parts of the region to highs of greater than 1400 mm per annum for the upper Swat basin and greater than 2400 mm per annum for the south west slopes of the Nanga Parbat massif. Within sub-basins, the authors also reported very great variability; mean annual yields from glacier ablation areas (from

ice melt alone without melt of seasonal snow cover or summer rainfall) can be greater than 2500 mm per annum. Temporal variability in discharge is another outstanding feature of the Upper Indus Basin that was demonstrated by the authors. Summer snowmelt, in combination with glacier ice melt, produce the very high peaks of mid and late summer monthly discharges for the Indus at Besham, the Kabul at Warsak (large snowmelt contribution) and the Hunza at Dainyor (highy glacier covered). Monsoon rains in the later periods in the Front Ranges, increase the spring and summer snowmelt to produce even higher instantaneous discharges.

Hewitt et al. (1989) and Wake (1989) stated that the annual precipitation for Hunza River basin above 5000 m in elevation is on the order of 1800–2000 mm. This elevation and precipitation are instrumental in creating large glaciers and perennial snow, which slowly moves down to the ablation zone and contributes to the river flow in summer. The climate variables (temperature and precipitation) observed at all the climate stations in the Hunza River basin are almost as well correlated with Hunza river runoff as the Gilgit climate station variables. The regression analysis suggested that Khunjerab climate station is the most active hydrological zone for Hunza River flows. A small drop in the percentage of snow cover in summer will have a significant impact on catchment runoff.

Linear regression analysis by Archer (2003) suggests that a 1°C rise in mean summer temperature arising from climate change would result in an increase of 17% in summer runoff for the river Shyok and a 16% increase for the river Hunza respectively. Together these two catchments contribute more than 25% of the inflow to Tarbela Dam, which is the main controlling structure for the Indus Basin Irrigation System, one of the world's largest integrated irrigation net-works (Fowler 2005 and Archer).

Analysis of the relationship between climatic parameters and stream flow in the upper Indus carried by Archer (2003) showed distinct differences between high and low elevation catchments. It was observed that in the high elevation catchments such as the Hunza and Shyok summer stream flow is mainly controlled by energy input, whilst in lower and more southerly tributaries such as the Astore and Kunhar variations in summer runoff are primarily related to the preceding winter precipitation. Modeling and forecasting the runoff using energy inputs to snow and ice melt in the upper Indus basin is limited by the sparseness of the climatic network, the unrepresentative location of stations on valley floors and the limited number of variables in the snowmelt energy budget that are typically measured (Archer 2004). As per (Archer 2004), though primarily snow- and glacial-melt feed the runoff from the upper Indus basin, the southern slopes of the Himalayas receive direct runoff from summer monsoon precipitation. Mountain valleys are predominantly arid but heavier precipitation falls as snow at higher altitudes, is stored during the winter months and released through melt at progressively higher elevations through spring and summer. Stream flow in the upper Indus thus depends jointly on the depth and extent of snow and ice and the energy available for ablation.

Archer (2003) carried out the statistical analysis for 15 gauged catchments in the upper Indus Basin and studied linkages between summer runoff and preceding and current precipitation and temperature. Middle altitude catchments south of the Karakoram observed a summer flow predominantly defined by the preceding winter precipitation, whilst high altitude Karakoram catchments (River Hunza at Dainyore Bridge and River Shyok at Yogo) with high glacierized proportion had summer and annual runoff strongly dependent on concurrent energy input represented by seasonal temperatures. Significant correlation coefficients between monthly runoff and monthly temperature were observed for the two high elevation catchments. It was observed that despite the differences in elevation and distance from the runoff sources, significant monthly correlation of runoff with the current month mean temperature was achieved throughout the melt season from April to September for both catchments. The analysis revealed a weak correlation during summer between runoff in one month and temperature in the previous month that the author partly related to serial correlation in monthly temperature and partly to lag in catchment response. Hence such relationships cannot be assumed to provide a basis for flow forecasting and indicate a limited scope for monthly flow forecasting on these catchments. The author further identified episodic monsoon incursions with associated cloud and rain and their impact on temperature impacting flow forecasting in the upper Indus Basin.

Valley floors and levels below 3000 m receive little precipitation (generally less than 200 mm per annum) and therefore contribute little to runoff. There is considerable topographic enhancement of precipitation; at 4000 m annual precipitation of greater than 600 mm may be expected (Cramer 1997) whilst Wake (1989) has suggested annual snow accumulation rates of 1500–2000 mm at 5500 m elevation. The zone of intermittent melt reaches 4000 m from late March to mid-November, and continuous melt of any remaining snow at this level can be expected to occur from late May to late September (Archer 2004).

Rees and Collins (2006) believe that if all Himalayan glaciers were to disappear, there would be a much greater impact on the water resources of the west than the east, with reduction in annual mean flow of about 33% in the west, but only about

4–18% in the east, compared to 1990 levels, because of the climatic differences between the drier western and monsoonal eastern ends of the region. They note that high discharge from glacier ice melt often dominates flow for considerable distances downstream, particularly where other sources of runoff are limited. They also speculate that, should Himalayan glaciers continue to retreat rapidly, water shortages might be widespread within a few decades.

Archer and Fowler (2008) carried out a study to forecast seasonal runoff on the River Jhelum, Pakistan using meteorological data. The authors investigated the links between climate and runoff for eight gauging stations in the Jhelum catchment and later studied the impact of seasonal forecasting of spring and summer in flows to Mangla Dam which is a major controlling structure contributing to the Indus Basin Irrigation System. Observed climatic variables, precipitation and temperature, from valley stations were used to forecast summer season flows at stations upstream from the reservoir with a lead time of up to three months based on multiple linear regression models built using data from 1965 to 1979. The analysis of the results revealed that good forecasts within 15% of observed flows for 92% of years can be achieved for summer season flows from April to September over the 1980–1991 validation periods. For spring flows from April to June, excellent forecasts can be provided within 15% of observed flows for 83% of years. The authors concluded that such measurements provide a useful basis for practical water management.

However, in the main Indus River, Ali et al. (2009) did not identify a significant change in flow, neither on the basis of the inflow into Tarbela (1961–2004) and at Kalabagh (1922–2002) nor in the Jhelum River measured at Mangla (1922–2004). An increasing trend was observed in the flow of Chenab measured at Marala (1922–2004), and a significant decreasing trend was observed in the flow of Kabul River at Nowshera (1961–2004).

In a study of intermediate spatial scale in the Hunza, Gilgit, and Astore river basins, Akhtar et al. (2008) considered three hypothetical glacial depletion scenarios: total disappearance of glaciers, 50 % disappearance, and no disappearance from 2071–2100 at a spatial resolution of 25 km. The study found that both temperature and precipitation tended to increase towards the end of the twenty-first century. The models showed an increase in discharge with both a 100 % and a 50 % reduction in glaciers, whereas with 0% reduction in glaciers, less water was available.

In a study that compared the drier, western Himalayas with the monsoon-dominated, eastern part, Rees and Collins (2006) suggest that climate warming would not have a uniform effect on river flow in the region. In a study of the Sutlej River basin, Singh and Bengtsson (2004, 2005) showed that climate change is going to impact seasonal water supplies more than annual water supplies. Reduction of water supplies during the summer months is likely to affect agriculture and tourism adversely in many areas.

For the upper Indus basin, Immerzeel et al. (2009) found that glacier melt contributed substantially to streamflow, 32% in a reference situation and peaking in July, with snow melt providing 40% of the total with a peak in June, and rain comprising 28% with a peak in July. The removal of all glaciers, with an accompanying increase in the winter and summer temperatures of 4.8°C and 4.5°C, respectively, and precipitation increases of 19.7% and 15.7% (climate model scenario for 2071-2100) indicated a reduction in summer maximum flow of approximately 30%, and a reduction in the percentage of total precipitation falling as snow from 60% to 48%. In these types of projections there is typically an increase in total precipitation, summer and winter, with melt from snow cover remaining about the same and peak discharge appearing approximately one month earlier than present conditions. Patterns of increased total precipitation and earlier snow melt could actually be beneficial for agriculture, as this pattern would provide more water for local irrigation and increased input to reservoirs when they are most empty at the beginning of the growing season.

Immerzeel et al. (2010) used Normalized Melt Index (NMI) in the Indus basin from 2001 to 2007 to quantify the importance of melt water from the upstream areas on overall basin hydrology. It was observed that under the present day climate, melt water plays an important role in the basin with discharge generated by snow and glacial melt accounting for151% of the total discharge naturally generated in the downstream areas. As per the authors, regardless of the compensating effects of increased rainfall in the Indus basin with high NMI, the summer and late spring discharges are eventually expected to be reduced consistently and considerably around 2046 to 2065 after a period with increased flows due to accelerated glacial melt.

Immerzeel et al. (2010) while working on spatiotemporal trends in snow cover in the upper Indus basin from 1999 to 2008 observed a significant negative trend for winter snow cover. They concluded that there are indications that climate change is affecting the hydrology of the upper Indus basin due to accelerated glacial melting. This conclusion is primarily based on the observation that the average annual precipitation over a five-year period is less than the observed stream flow. The annual melting rate is conservatively estimated at 1% of the total ice reserve.

Miller and Rees (2011) have summarized likely changes in the contributions of glaciers to river discharge in the Indus basin. The authors reported that glacial melt contributed significantly to the water discharge of the Indus because in this area the summer monsoon is weak and the contribution is more obvious in the arid areas downstream.

A recent study by Immerzeel et al. (2011a) combined a high resolution cryosphere-hydrology model to deal with various uncertainties in climate change projections and used it to investigate how glaciers and runoff would respond to an ensemble of downscaled climate model data in the Langtang catchment in Nepal. These projections showed both an increase in temperature and precipitation and a concomitant steady decline in glacial area, which would lead to a significant increase in river flows.

Gain et al. (2011) investigated the effect of climate change on both low and high flows of the lower Brahmaputra. The authors applied a novel method of discharge-weighted ensemble modeling using model outputs from a global hydrological models forced with 12 different global climate models (GCMs) and resulted in a multi-model weighted ensemble of transient stream flow for the period 1961–2100. The analysis showed that extreme low flow conditions are likely to occur less frequent in the future. However, a very strong increase in peak flows is projected, which may, in combination with projected sea level change, have devastating effects for Bangladesh. The authors concluded that methods presented in the study are more widely applicable, in that existing multi-model stream flow simulations from global hydrological models can be weighted against observed stream-flow data to assess at first order the effects of climate change for specific river basins.

A different study based on precipitation and stream flow models on a large-scale basin, the Niyang River basin in south east Qinghai (Tibetan Plateau, China), indicated significant increasing trends in stream flow, both annual and wet season, without any significant difference in precipitation (Zhang et al. 2011). The warming climate accelerated glacial melting, as evidenced by increased summertime stream flow. These studies underscore the point that to achieve a reliable assessment of the impact of climate change on hydrology in the HKH region, there is a need to carry out this level of analysis in representative catchments covering the entire spatial range of the region.

High correlation coefficients between total winter precipitation and annual runoff for River Jhelum have been reported, whilst summer precipitation was found of little use in estimating annual flow (De Scally, 1994). The upper Indus and the River Shyok have low annual runoff but totals gradually increase downstream with the receipt of tributary flows with higher runoff. The Hunza and Gilgit rivers contribute runoffs between 700 and 800 mm and nearly double the runoff rate in the overall Indus catchment below the confluence (Archer 2003).

The precipitation measurements at standard valley climate stations can be used as a basis for forecasting the volume of flow originating in the upper Indus. However, flow originating in high altitude snowfields and glaciers of the Karakoram is little dependent on snow-covered area. Alford (1992) suggests that annual variations in runoff in the Karakoram probably depend primarily on melting rates in summer and that a sunny summer can be expected to give higher runoff at the expense of glacier storage. In contrast he indicates that runoff from the sub-alpine zone south of the Karakoram Range ought to be bigger after an unusually snowy winter.

d) Climate Change Impacts on Freshwater Resources

As the mountains are the source of the region's rivers, the impact of climate change on hydrology is likely to have significant repercussions, not only in the mountains, but also in populated, lowland regions that depend on mountain water resources for domestic, agricultural, and industrial purposes as well as hydropower generation (Singh et al. 2011). The seasonal character and amount of runoff are closely linked to the wetland ecosystems and the cryospheric processes of snow, ice, and glaciers. Glacial melt influences discharge rates and timing in the rivers that originate in the mountains. There is growing concern that climate change may accelerate the damage to wetlands and freshwater ecosystems such as lakes, marshes, and rivers. The response of lakes and streams to climate change will involve complex interactions between the effects of climate on runoff, flow volume, hydrology, catchments, and in-lake processes. Climate change is expected to increase the temperature of lakes, streams, and other water bodies with unpredictable consequences for many aquatic species. In lakes and streams, warming will have the greatest biological effects at high altitudes. Altered precipitation and temperature patterns will affect the seasonal pattern and variability of water levels in wetlands, potentially affecting valued aspects of their functioning such as flood protection, carbon storage, water cleansing, and waterfowl/wildlife habitat (IPCC 1998).The geographical distribution of wetlands is likely to shift with changes in temperature and precipitation, with uncertain implications for net greenhouse gas emissions from wetlands. Changes in these ecosystems could have major negative effects on freshwater supplies, fisheries, biodiversity, and tourism. Inputs of nutrients and other pollutants into aquatic habitats will vary with rainfall and other characteristics of the watershed. One of the ways that climate change could affect freshwater biodiversity is by altering the carbon to

nitrogen (C:N) ratio in riparian vegetation (Allan et al.2005). This change in nutrient quality could lead to corresponding changes in biological assemblages, enhancing organisms that use carbon efficiently, while suppressing those that depend on larger nitrogen inputs. The changes in temperature and precipitation can have uncertain implications for net greenhouse gas emissions from wetlands. Changes in these ecosystems could have major negative effects on freshwater supplies, fisheries, biodiversity, and tourism. Inputs of nutrients and other pollutants into aquatic habitats will vary with rainfall and other characteristics of the watershed.

3.2. Impact of proposed hydropower projects on water resources

Out of the identified hydroelectric potential of about 20,000 Mw in the Indian controlled Jammu and Kashmir, only 2327 MWs (14%) have been exploited so far consisting of 767 MWs in the state sector from 21 power projects and 1560 MWs from the three power projects under central sector. The installed capacity of 767 MWs from state sector projects include the 450 MWs flagship Baglihar Phase, 105 MW Lower Jhelum HEP, and 105 Upper Sindh II. In the central sector the three implemented projects of NHPC are 690 MW Salal, 480MW Uri I and 390 MW Dulhasti. There are about 5 power development projects under construction in the state sector and these include the Bagliar-II, Pahalgam, Matchil, Snajak and Bhaderwah and the total power generation from these projects adds up to 453 MW only. Further, 7 more hydropower projects were transferred to NHPC in 2000 by virtue of a MoU signed between the Chief Minister of J&K and Union Power Minister, G.O.I, for their development on a fast track basis. Even though these projects were prioritised in the 9th plan and were to be taken up in 10th plan, they have now slipped to 11th Five Year Plan. With the exception of the two major projects like Bursar and Pakaldul, the work on the other projects has already started (J&K economic survey report, 2007-08). These projects include Sewa-II, Kishenganga, Bursar, Pakaldul, Nimo-Bazgo, Chutak, and Uri-II and the total generation from these seven power projects amounts to 2799 MW. As of today, about 1800 MW hydropower is with the National Hydropower Corporation (NHPC), a subsidiary of the Government of India, for development under the central sector and another about 2120 MW hydropower generation has been planned for development under joint venture arrangement between NHPC and the Jammu and Kashmir State Power Development Corporation (JKSPDC), a subsidiary of the Government of Jammu and Kashmir.

Of late the state of Jammu and .Kashmir has allowed some hydropower development in the private sector. Around 100 MW capacity of mini HEPs besides 690 MW Rattle HEP are now getting developed in private sector. As per the J&K Economic Survey Report (2007-08), the main projects planned for development under the 11th and 12th plans include Sawalakote I & II (1200 Mw) , NGHEP (93 Mw), Parnai (38 Mw), Lower Karnai (50 Mw), Kirthai-I (240 Mw), Kiru (600 Mw), Kawar (520 Mw) and Pakuldul (1000 Mw). The Government of India and the State of Jammu and Kashmir have thus set a target of developing on its own 453.61 MW of power during the 12th Five Year Plan.

This proposed hydropower development in the Upper Indus Basin (UIB) by the Central and State government in India has raised concerns in various sections of the Pakistani society and are being debated in the media and also among the scientific and administrative setup. Despite the Indus Water Treaty (IWT) for sharing of Indus waters between India and Pakistan, serious differences over water sharing, water management and hydropower projects continue to spoil relations between India, and Pakistan. Differences between India and Pakistan continue to create ill-will between the two on around 11 large hydroelectric projects India plans to construct, including the Baglihar Project over which a neutral expert appointed by the World Bank concluded his arbitration that seems not to be acceptable to Pakistan. More than the dispute over Jammu and Kashmir, the issue of the waters of Jhelum and Chenab has the potential to once again provoke people in Pakistan against India and push the two countries to war (Imtiaz Khan, 2006).

Although seldom analyzed, cumulative impacts occur when several power projects are built on a single river. They affect both the physical (first-order) variables, such as flow regime and water quality, and the productivity and species composition of different rivers. The problems may be magnified as more large power projects are added to a river system, resulting in an increased and cumulative loss of natural resources, habitat quality, environmental sustainability and ecosystem integrity. Though there is almost no study on the impacts of these cascading dams in any part of the UIB, however, in this subsection we have described some likely impact this proposed hydropower activity may have on various aspects of the environment and other related aspects studied in other regions of the world where such cascade of dams have been established.

Dam construction is considered the major factor contributing to significant modifications of river ecosystems (He et al., 2004). It is probably one of the greatest stressors affecting the integrity of running waters (Garciade Leaniz, 2008), because it can interfere or even stop the transport of sediment and nutrients along waterways and eventually disturb ecological connectivity, which underpins the transfer of materials and products of ecological functions and processes (Jenkins and

Boulton, 2003). Additionally, impounded waters can trigger important changes in the composition of stream fauna, favoring lentic over lotic species (Raymond 1988; Lewis2001; Shao et al.2007; Zhou et al. 2007), changes in the hydrology, river morphology and habitat (Williams and Wolman, 1984; Vörösmarty et al., 2003; Hu et al., 2008). Since the operation of Hoover Dam and a few other dams in the United States and Mexico, little water reaches Colorado's estuary in the northern Gulf of the California (Lavín and Sánchez, 1999; Schöne et al., 2003). Due to the construction of dams and reservoirs, the water renewal time of rivers has significantly increased from 20 to 100 days (Kummu and Varis, 2007). Williams and Wolman (1984) report that sedimentation in reservoirs and scour in the river-bed in downstream reaches are the major reason for channel morphology changes. Impounding of waters can cause significant discontinuities in the transportation of sediments (Rădoane and Rădoane, 2005).

Cascade hydropower development projects can have serious ecological consequences like biodiversity loss, flow reduction, land use change, and can sometimes bring about a large-scale disturbance on rivers and is the most important factor to change the natural characteristics of rivers (Lopes et al., 2004). Therefore, whether to construct the cascade hydropower projects or not has brought about strong arguments and discussion worldwide (Brown et al., 1996; Hewitt, 1998; Chalise, et al., 2003; Graf, 2005). The number of studies on ecological effects of the cascade dam constructions around the world has increased with the increasing of the ecological problems induced by the cascade dam constructions. Many methods like habitat simulation, contrastive analysis, etc., have been used in the studies. Studies in the past mainly focused on the biodiversity (Wernstedt, et al., 1995; Mrakovcic et al., 1995;Gertsevet al.,1999; Bombino, 2006; Johnson, et al., 1995), sediment transport (Kummu, 2007) hydrological characteristics (Lopes et al., 2004; Haritashya et al., 2006), river channel morphology (Marks, 2006; Brandt, 2000), land use types (Verbist et al., 2005) etc.

From the previous reviews, it can be seen that the ecological effects of cascade hydropower projects differ greatly depending on location, operation time, environment, substrate, bank material, released water and sediment, etc. Also, it can be seen that earlier studies on the impacts of cascade dams have mainly focused on single indicators. Ecological effects of the cascade hydropower projects in Lancang River region of the Longitudinal Range-Gorge Region have been studied by many scientists, who have mainly focused on the water quality (Zhang et al., 2005), water temperature (Ye et al., 2008) and trans-boundary effects (He D. M, 2006; Fu et al., 2003). A few studies on these subjects have been carried out about the Yuanjiang River-Red River region. The impact of cascade hydropower projects on regional ecosystems are extremely complex, because of not only the complexity of the ecosystem itself, but also the accumulation of the ecological effects between cascade projects. That is why it is not accurate enough to study the effects on single indicators or single ecosystem types.

The river impoundment affects the downstream environment so the power projects built in the same catchment, either in series (i.e. along the same river) or in parallel (i.e. on different tributaries) will inevitably result in cumulative impacts. A cumulative impact can be defined as the incremental effect of an impact added to other impacts. An individually insignificant impact may, when combined with others, produce a major change within a river ecosystem. The total effect on a river ecosystem of cumulative impact may be greater than the sum of each individual impact. Therefore, to understand the ecological effects more clearly and forecast the ecosystem changes more correctly, an integrated study must be carried out at the regional ecosystem scale because of the large number of cascade hydropower projects planned along the Chenab River in the UIB.

The cumulative impact of inter basin water transfers can be of special concern, as this often involves the transfer of species into new watersheds. Flood regimes are clearly affected as increasing the total storage volume by adding additional dams reduces the flood flows downstream. In Pakistan, the Tarbela case Study reveals that only 21% of the historical dry season flow of the Indus reaches the delta; the rest is diverted for irrigation and water supply by 22 dams and barrages. Since the Kotri barrage was commissioned in the early 1960s, the average number of days with no river flows downstream in the dry season increased from zero to 85 (the average from 1962 to 1997). Similar impacts of cascade hydropower projects have been observed around the Aral Sea and in Australia where 80 years of river regulation, construction of additional storages, and diversion of water from the Murray Darling River have reduced the median flow reaching the sea to 21% of the pre-regulated flow. Water quality parameters recover only slowly when water is released from a dam. Oxygen levels may recover within a kilometre or two, while temperature changes may still exist 100 km downstream. Where the distance between dams does not allow recovery to natural levels, the biology of many hundreds of kilometres of river may be affected by a handful of dams. In the Orange-Vaal River in South Africa, the impact of 24 dams may have led to 2300 km (63%) of the river having a modified temperature regime. On the Columbia River, Grand Coulee dam receives water that is already high in total dissolved gasses as a result of upstream Canadian dams.

Before the levels can recover to natural values, spill at Grand Coulee increases them again, passing the problem further downstream.

Construction of a series of dams may therefore have increasing impacts on downstream ecosystems and biodiversity. Also on the Columbia River, the cumulative impact of additional dams on salmon migrations has been found significant. It is estimated that 5–14% of the adult salmon are killed at each of the eight large dams they pass while swimming up the river. What is not well researched is the change in the magnitude of the incremental response of ecosystem function and biodiversity as a river is increasingly fragmented. Thus, it is not known if there is some threshold level at which the marginal impacts of the addition of one or more dams to a particular cascade of dams will begin to decline. It is therefore a case-by-case call whether the ecosystem impacts of further modifying a particular river may at some point be of less consequence than, for example, putting the first dam on a free-flowing river.

A case study was conducted on Lancang River region and Red River region, to find the ecosystem changes under different cascade hydropower dam construction scenarios. The hydro-energy of Yuanjiang River and Red River was mainly concentrated on the tributaries. Only 15.7% of the total equipped capacitor and 19.4% of generating capacity were produced on the mainstream of the Red River region. Most of the dams on Yuanjiang River and Red River have been planned with small regulation capacity because of the unsuitable natural conditions. It is generally believed that a cascade construction can have extensive influences on river ecosystems in more aspects than a single dam. As the developments of cascade power projects may lead severe consequences, the ecological security of the river has become the hot issue. The construction and operation of cascade projects on transboundary rivers involves strict adherence to the bilateral or even multilateral frameworks and treaties, therefore it often gets more complex and sensitive than a mere environmental issue.

The hydrological and environmental response after the construction of eight cascade dams has been a concern along the upper reach of the Yellow River (Cai and Rosegrant 2004). The hydrological alteration due to the dam along the middle reach of Yellow River has been investigated, and it was found that the Xiaolangdi Reservoir had changed the natural flow regime downstream (Yang et al. 2009).

The stream flow characteristics at the inlet and outlet of the cascade section, before and after the cascade hydropower project construction, show that the stream flow volume from upper catchments has been reduced due to the impact of the cascade dams. The yearly volume difference between the inlet and outlet dropped from 82×108 to $55 \times 108 m^3$, a decrease of 33%. This drop suggested that the cascade dams slightly offset general runoff. The inlet monthly peak decreased from 1,425 to 864 m^3/s, and outlet monthly peak decreased from 1,855 to 979 m^3/s. The difference between peak volumes declined from 430 to 115 m3/s, which suggests that the cascade dams reduced the peak waterflow value. The statistical analysis of the stream flow indicates that the inlet hydrological feature did not intensively vary, but the cascade dams significantly disturbed the outlet stream flow.

The Longitudinal Range-Gorge Region (LRGR), composed of the Hengduan Mountains that are related to the Tibetan uplift and the adjacent mountain-valley regions in south-north direction, lies in south-western China (He et al., 2005). Four famous transboundary rivers flow through the LRGR, i.e., Yuan-Red River, Lancang-Mekong River, Nu-Salween River and Irrawaddy River. For three of them, cascade hydropower dams have been planned and some are already constructed on the main channel. The development of cascade hydropower projects may alter the structure and function of river ecosystems. The related ecological effects of these constructions on flow patterns, water quality, sediment etc. have led to increased concerns in recent years, especially in the Lancang River Basin. The imposition of dams can cause rapid environmental changes. The Manwan Dam on the main stream of the Lancang River has had substantial ecological effects in the reservoir and downstream of this dam. By 1996, three years after the closure of Manwan Dam, siltation had increased the elevation of the reservoir bottom to a level 30 m higher than before construction (He et al., 2004).

Water quality had degraded (Zhang et al., 2005) and surface water temperature in the reservoir was higher than before the dam construction. He et al. (2006) report that the operation of Manwan and Dachaoshan Dams influenced the flow patterns of the Lower Mekong River, though the alteration was not a major factor. However, once the two largest dams, Xiaowan and Nuozhudu, are completed, the seasonal regulating capacity of Lancang Cascade will reach 100%, which will result in obvious effects on the distribution of water volumes (He et al., 2006). Kummu and Varis (2007) propose a theoretical method to predict the amount of sediment trapped in the reservoirs on the Lancang-Mekong River. Ecological engineering strategies aim to provide a sustainable ecosystem that benefits both human society and the natural environment.

The soil erosion intensity of the Lancang region increases with advancing development of the cascade dams. The most serious soil erosion occurs midstream and downstream before and after cascade construction. Total storage coefficient increases continuously due to the development of the cascade dams,

especially with the operation of Xiaowan Dam and Nuozhadu Dam. At the same time, increasing siltation resulting from the dams operation leads to loss of reservoir capacity. There is a significant change of width–depth ratios on the Lancang River before and after the construction of the cascade dams. The width–depth ratios in all river cross-sections distinctly decrease. Sediment trapping is one of the main problems induced by the construction of the cascade dams on the Lancang River. River densities significantly change before and after the dam constructions.

3.3 Any other concerns about water by any of the stakeholders

a) Floods:

The great Indus flood of 2010 and the unprecedented extent of the devastation resulting from it cannot be understood, or mitigated, in isolation from the 'routine' river management of the basin. The cultural, economic and social geographies of water use, distribution and regulation in the Indus basin are integral links in the causal chain of events that led to the disaster (Mustafa and Wrathall, 2011). The disaster is, therefore, deeply human in its genesis, even to the extent that the anomalous monsoonal pattern that triggered the floods may be linked to anthropogenically-induced climate change – after all the weather anomaly observed in 2010 has recurred in a milder form about three times in the past decade, whereas it was seen only every few decades in the last century (NOAA, 2010a). The relationship between anthropogenic environmental degradation and catastrophic flooding in Asia, Latin America, Europe and other regions is well documented (Gregory, 2006; Wisner et al., 2004; Smith, 2001; Alexander; 1992). Conversely, we know there is an established link between healthy watersheds with flow capacity – wetlands, marshes, estuaries and mangroves and flood mitigation (DEFRA, 2002).

The great floods of 2010 in the Indus basin of Pakistan have been declared the worst calamity to hit the country in its history and to hit the world in the 21st century. The flooding affected 6.88 million ha of Pakistan's most fertile valleys destroying 2.4 million ha of standing crops, 24 per cent of the 9.7 million ha sown in 49 of 81 flooded districts (UN-FAO, 2011; SUPARCO, 2011) with total damage estimated at US$2.9 billion to the agricultural sector alone. The 2010 flooding stems from a confluence of events associated with a warming planet. In July, when monsoon rain began in Pakistan, 2010 was already the hottest year on record, and high glacier runoff had already filled rivers to capacity (NOAA, 2010a). Evaporation rates over the hotter-than-average Indian Ocean soared, leading to especially active monsoon weather (PMD, 2010), and the oceanic phenomenon, la Niña, is thought to have exacerbated the severity of monsoon activity (NOAA, 2010b; Riebeek, 2010).

As Michael Blackburn from University of Reading explains, both the fires in Russia and the precipitation activity in Pakistan were globally linked through an unusually strong polar jet stream, which stalled unprecedented levels of moisture over the Himalayas (Marshall, 2010; NOAA, 2010a), pouring into the Indus valley an unprecedented volume of precipitation (UN-OCH A, 2010). Evidence of climatic changes cannot be deduced from a single meteorological event; nevertheless, the number of exceptionally heavy monsoons over India has doubled in the last 50 years, while at the same time moderate and weak precipitation has decreased (Pal and Al-Tabbaa, 2010; Goswami et al., 2006)

b) Food Security:

Water from the Hindu Kush-Himalayas and the central Asian mountain region supports the production of over 500 million tons of cereals per year, equivalent to nearly 55% of Asia's cereal production and 25% of the world production today. As per Nellemann and Kaltenborn (2009), climate change may not only disrupt monsoon patterns but may also significantly alter the main flow and seasonality of many of the large Asian rivers within a few decades with disastrous impacts on food production. Some estimates suggest that due to environmental degradation in the watersheds, floods, and reduced water flow due to climate change in the Hindu Kush - Himalayas, cereal production in Asia could become 10% to 30% lower than projected demand, corresponding to a 1.7–5% global reduction in cereal production (Nellemann and Kaltenborn, 2009; UNEP, 2009). Habib Zaigham in an article in Water for Food and Rural Development in 2000 calculated that 80% of Pakistan's food needs were fulfilled domestically. But she also predicted that due to degradation in land, increased salinization, and decreased waterflow that was not a sustainable mark. Furthermore, she reported that revenue from agriculture only pays for less than 40% of the cost of irrigation

In HKH region, for example 80 per cent of agriculture is rain fed where changes in rainfall will have a significant social and economic impact. Meanwhile, it is estimated that a temperature increase of 2 to 3.5 degrees celsius in India could result in a decline in farm revenues of between 9 and 25 per cent. The International Rice Research Institute, for example, estimates that for every degree celsius of night time temperature increase, there is at least a 10 per cent decrease in rice production in the African region. While some areas will benefit from longer growing seasons (such as northern Asia), changes in water regimes will render other areas unsuitable for traditionally-grown products, and other areas will become susceptible to

new forms of crop and livestock diseases. In regions already affected by food shortage and famine, this could cause further disruptions in food supply. Increasing temperatures and water stress are expected to lead to a 30% decrease in crop yields in central and South Asia by the mid-21st Century (UNDP 2006). At high altitudes and latitudes, crop yields should increase because of reductions in frost and cold damage. It will be possible to grow rice and wheat at higher latitudes than in currently the case in China (Bajracharya et al., 2008).

Irrigation is the backbone of the agricultural system in the Indus basin and agriculture is a major contributor to local economies; in Pakistan, 22% of the GNP is contributed by agriculture. Though irrigated areas and agriculture production has increased considerably in Pakistan over the time but the yields are still less as compared to various countries of the world. Furthermore, huge spatial variation in cropping pattern and productivity of land and water within irrigated agriculture of Pakistan has become a chronic issue. There are various reasons causing low production (Tahir and Habib, 2000).

The Indus basin irrigation system in Pakistan is the world's largest; estimates suggest that snow and glacier melt contribute more than 45% of the total flow to this system. During the dry season the flow from the mountains is particularly important, accounting for all the total flow in the uppermost parts of the catchments. The basin is already water stressed. In Pakistan about 13 million ha of cultivable land remains barren because of water shortage (Shreshtha et al., 2010). Pakistan's agricultural sector is dominant in the economy of Pakistan. The sector not only meets the food demand of the growing population but also provides the raw materials for the industrial sector, notably cotton for the textile industry. The sector employs around 45% of the total labor force of the country whilst the 67% of the population living in rural areas is linked directly or indirectly to agriculture for their livelihoods (Archer at al., 2010).

Increasing water scarcity poses a threat to food security and safe domestic water supplies. Irrigated agriculture is a major driver in leading to water scarcity because of its high consumption of water resources (Molden, et al., 2001). The authors opine that obtaining more benefits from each drop of water consumed, especially from each drop irrigated agriculture consumes, will be key to mitigating problems of scarcity. They have discussed and illustrated the concepts for identifying the ways of improving productivity of water within Indus basin in Pakistan.

Upstream discharge and downstream food security of the Indus basin are the most sensitive to climate change owing to the large population and the high dependence on irrigated agriculture and melt water (Immerzeel et al., 2010). The authors predicted a decrease of 26.3 + 3.0 million people that can be fed in the Indus basin owing to the changing climate. In Pakistan, for example, one of the countries with the highest water scarcity and extreme dependency on the Indus River, the population is projected to increase by 82% from around 184 million in 2010 to around 335 million by 2050. In some regions of the basin, as in Pakistan, water demand will increase by 50–70% by 2050, while availability will decline at the same time. Relating the changes in the upstream water availability to net irrigation requirements, observed crop yields, caloric values of the crops, and required human energy consumption, estimations have been made for change in the number of people that can be fed in the basin (Siebert et al. 2005). Muslim et al., (2012) predicted that under the changing hydrology and climate, the rice production in the Jhelum basin in the UIB shall decline by 30% from 4.3 tons/ha in 2010 to 3.05 tons/ha by the end of this century.

Climate change in the Indus basin can also have a profound effect on upstream water supply to the Indus Basin Irrigation Systems in the Indus basin. Upstream water supply is crucial to sustain upstream reservoir systems, which are used to store and release water to downstream areas when most needed. Irrigation water for the Indus Basin Irrigation System, which is the largest irrigation network in the world, is, for example, regulated through two major storage dams (Tarbela dam on the Indus River and the Mangla dam on then Jhelum River). Both are located in the upper Indus basin and are fed predominantly by melt water. Any change in upstream water supply to these dams will have a profound effect on millions of people downstream.

Ravindranath et al., (2011) have recently developed a set of indicators for the key vulnerability sectors, such as agriculture, forest, and water, to calculate the future vulnerability to climate change in the northeastern region of India. Agriculture, particularly rain fed agriculture, is extremely sensitive to climate change and probably will be affected (Ramay et al., 2011). Recently Kumar et al., (2011) investigated how climate change would affect crop productivity in the northeastern region of India and found that by 2030 the production of irrigated rice would increase by up to 5% but that the areas where rain fed rice could be cultivated would probably decrease by 10%. They went on to predict a 40% reduction in the production of irrigated maize and a reduction of 20% in the production of wheat but an increase of 5% in the potato crop.

c) Glacial Lake Outburst Flooding (GLOF)

It is reported that from the past records that at least one GLOF event has been reported to occur every 3 to 10 years

in the Himalayan region (Bajracharya et al., 2008). As reported by Young and Hewitt (1989), glacier outburst floods occur throughout the Karakoram and several classic events have taken place during the century which have been well documented by Hewitt (1982). The authors report that the truly catastrophic floods on the Shyok of 1926 and 1929 (Gunn et al. 1930; Mason 1929) have not been equaled in recent years, although there have been some relatively small floods which have still proven disastrous for the people living in the region. It was reported that during the 1929 flood on the Shyok, the Indus system river stage at Attock, some 1200 km from the glacier dam, rose 8.1mm.

In 2009, satellite imagery revealed a sudden advance of the Chong Khumdan glacier into the Shyok River. Previously, between 1926 and 1932, this glacier formed a series of large ice dams and at least four outburst floods were reported that resulted in a measurable rise in the river 1,100 km away at the Attock gauging station. Hewitt (2010) noted that in the Karakoram, there is a greater prevalence of ice-dammed lakes formed by advancing glaciers (typically short-lived and unstable), in contrast to moraine-dammed lakes, which are more typical in the east and associated with greater rates of melt.

There is evidence for increasing incidence of glacial lakes and outburst floods in the Himalayas associated with glacial retreat (Watanabe et al., 1995). Such evidence is lacking amongst the larger glaciers of the Karakorum where some are still advancing or surging (Hewitt, 1998). Periodic surging advance of the tributary Khordopin glacier into the Shimshal valley, blocking runoff in the main valley continues to cause problems. Nevertheless the frequency and severity of such large outburst floods appears to have diminished since the two reported periods of concentrated activity in the Karakorum from 1890 to 1905 and 1925 to 1935. The climate and glaciological conditions associated with floods during these periods have not been established so the recurrence of such extreme floods cannot be ruled out. While snow and glacial melt provide the majority of annual maximum floods, it is the unusual floods resulting from landslides, dam breaks or glacial lake outbursts which exert main influence on flood frequency at higher return periods (Archer, 2002).

It is recorded that of all the glacier dams in the Karakorum region, 35% of the destructive floods have been recorded over the past 200 years (Hewitt, 1982). Most of the glacial lake outbursts in the Karakorum have resulted from the surging advance of glaciers across major headwater streams, blocking the river flow in an ice free valley (Archer, 2002). Several events of much larger magnitude arising from both GLOFS and dam breaks has occurred over the past century on both the Hunza and Gilgit rivers. One of the major GLOF was reported in 1960, originating from a tributory in the Shimshal valley and reportedly caused the destruction of most of the houses and terraces in the Passu town. Further major GLOFs occurred from Shimshal in 1833, 1884, 1893, 1905, 1906, 1907, 1927, 1942, whilst minor floods occurred in 1980 and 2000 from the same source. Similar events although of smaller magnitudes have been frequent on the Gilgit River. These include an event on the Yasin tributary at Drakot in 1978 (Whiteman, 1985) and on the main Ghizer at Jug Bargo in 1999. There have been a number of recent floods arising from GLOFs on small tributaries in addition to the one reported at Sosat in the UIB in 1995. These include Khaltu in 1980, Gulogah in the Ishkoman valley in 1984 and Khankui 1999. While these floods and accompanying debris flows caused serious damage at the site, surprisingly no floods were reported at Gilgit. However, major GLOF floods are reported to have occurred also on the Ishkoman tributary in 1844, 1865, 1893 and 1905. The 1905 flood has passed into the folklore of Gilgit as the largest and the most damaging flood, rising 20ft above the normal summer level. GLOFs and dam break floods exert an even greater impact on the tributary valleys from which they originate.

Romshoo et al (2012) have assessed the potential damage to the hydropower infrastructure due to the potential damming of the water in the form of Glacier Lake at the snout of the Panjtarni glacier using BREACH model and FLDWAV models. The study revealed that, in case of a glacial lake outburst near Panjtarni glacier, it will last for about 5 hrs and will have a peak discharge of about 293685 cusecs at about 4.21 hrs after the beginning of the outburst event. The studies revealed that the GLOF will have catastrophic effects up to 100 Km downstream the potential GLOF site. The computed discharge at the proposed Powerhouse site is about 69, 250 cusecs, that is almost 7 to 8 times the recorded peak discharge of the Sindh River in the UIB.

d) Pastureland productivity

Climate change has been reported to impact grassland productivity, ecosystems, and the distribution and composition of plant communities. Some rangeland has already degraded by 40% of dry land on the Tibetan plateau (Eriksson et al., 2009). In the Jhelum basin of the UIB, Shafi and Romshoo (2008) have reported degradation of the pasturelands that has affected the carrying capacity of the alpine pastures. Although livestock is the major source of income for a large proportion of the population, families are increasingly unable to maintain the same number of animals as before and also it is hard for them to take their herds to pasturelands for grazing. The local dairy enterprise has suffered as a result.

e) Water-logging and salinity

The allocation of the three western rivers of the Indus system to Pakistan under the 1960 Indus Water Treaty, and the development of irrigated agriculture that followed, certainly brought much prosperity to Pakistan or to some sections of the population, but an unanticipated outcome was the emergence and spread of the ills of water-logging and salinity. Out of a total of 18 million hectares (mha) of irrigated land in Pakistan, about 6.22 mha are said to be affected by this menace. In response to this the Government of Pakistan launched different Salinity Control and Reclamation Projects (SCARP), starting in 1959. These do not seem to have been very successful. Among the criticisms of the SCARP approach are design defects, severe environmental impacts, and the creation of secondary problems that are as bad as the original ones that the plan had intended to remedy. The impression that one gets is that Pakistan is still struggling with a gigantic problem to which satisfactory answers have not yet been found.

Soil salinity remains a hazard for the Indus basin and threatens the livelihood of farmers, especially the small-scale ones. Land degradation is reducing the production potential of major crops by 25%, valued at an estimated loss of US$ 250 million per year (Haider et al. 1999). Groundwater overdraft has also led to sea water intrusion in the coastal areas of the Indus basin which is threatening ecology of wetlands. Important aquatic resources, mangrove forests and coastal areas need to be protected. Mangrove forests cover 130,000 ha and are an important source of firewood and provide the natural breeding ground for shrimps.

Salinity and drainage effluent management problems exist side by side in the saline areas of Pakistan. The constrained drainage intake potential of rivers and water bodies and high effluent generation from irrigation in the saline lower Indus are the processes that need to be managed. The irrigation schemes in the Indus basin were not supported by a drainage infrastructure and low lying rivers were supposed to collect all excessive runoff. A part of the summer floods were stored in flood plains that had a low level of human activity and recollected in the rivers when ground water levels dropped, supporting sub-surface water movement. This process is greatly disturbed by extensive agricultural activity, industrial development and reckless urbanization along the rivers (Habib, 2004b).

Another important challenge that can be expected to arise with a change in water availability due to climate change is the issue of loss of productive agricultural land, land degradation and the contamination of surface and groundwater resources. All Indus Basin rivers are threatened by dryness in their lower reaches as a result of increased upstream diversions. The gradual shrinking of rivers reduces the natural recycling process of the flood plains and water bodies. The dry reaches phenomenon has extended over time span and across river stretches in the Indus and eastern tributary rivers, Ravi and Sutlej. The daily river data for a dry year shows nil flows in the whole year in the tail reaches of the Ravi and Sutlej, and more than ten months in the tail reach of the Indus. The reduced and nil flows in the river reach directly influences aquatic life and natural vegetation in the riverine (Sailaba or Kacha) areas. An indirect impact of these reduced flows is the decrease in groundwater recharge. The minimum water requirements of the Indus river have been roughly estimated by a preliminary study by the Ministry of Water and Power, Government of Pakistan. The study recommends four MAF annual volume as the minimum reach flows; 30 per cent of this flow is expected to be used within river reaches while the rest is conveyed downstream (Habib. Z, 2006). A required increase in environmental flows to sustain ecosystems within the rivers and the Indus delta will put pressure on other demand of the stakeholders and accelerate the tension between riparian countries (Laghari et al., 2011).

Climate change is not the only stress factor on the Indus Waters Treaty. Rising population in both nations has led to an increase in the demand for drinking water, sanitation and agriculture. To make matters work there is inefficiency in the transportation which increases the use of water, and also the number of businesses that rely on water have increased in number (Habib, 2005). Emerging domestic and industrial requirements are key factors competing for the use of water, while ecological imbalances, salinization, and aquifer depletion are typical consequences of the overuse of water resources in Pakistan (Habib, 2000). New water quantities and allocations are required for domestic and industrial uses and for use in planned agriculture, as well as to conserve groundwater aquifers, rivers, and lakes, protect aquatic life in these water bodies, and maintain water quality. Small users are most gravely affected by canal water scarcity, aquifer depletion, and land quality deterioration.

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CHAPTER IV

Common Concerns and the Roadmap to Resolution

Summary: This chapter discusses the common concerns, expressed explicitly or otherwise, in the two countries about the use of Indus water. In order to address these common concerns, a joint multi-partner initiative involving stakeholders from the two countries and beyond is proposed, that shall lead to the formulation of a roadmap for sustainable management of the Indus water system. The material and discussion in this chapter has been organized as follows:-

j) Common concerns in both the countries (and in Kashmir)

k) Proposed roadmap for addressing the common concerns

l) Involvement of academia, government and non-governmental actors to address "common concerns"

m) Informed diplomacy to deal with policy issues

We discuss here the common concerns and what needs to be done, in a cooperative framework, to generate a body of information and knowledge about these concerns so that a robust strategy is put in place basin-wide to address these concerns for the sustainable use of the depleting water resources in the basin. The roadmap for developing the robust strategies to address these concerns at the basin scale envisages cooperation and sharing of expertise and resources among various stakeholders. These stakeholders come from academia, governmental organizations, NGOs and other segments of the society and shall work under a consortium for generating the required knowledge for developing action plan for addressing the common concerns on the Indus water system. It is hoped that, the proposed initiative shall not only provide the knowledge and mechanism to address these concerns but inter alia build and strengthen the trust between the policy and decision makers of the two countries and encourage them to address other festering bilateral problems confronting the two countries.

Water security is emerging as an increasingly important and vital issue for both India and Pakistan. Many regions in the two countries are beginning to experience moderate to severe water shortages, brought on by the simultaneous effects of agricultural growth, industrialization, urbanization, population growth and climate change. In the future, diminishing and degraded freshwater resources could lead to internal instability across the south Asian region. India and Pakistan have shared five river basins under the trans-boundary Indus Water Treaty (IWT) since 1960. The treaty sets national water rights on the rivers and some obligations linked to the development works, but does not have any institutional provisions to address any of the issues related to water resources management at the basin scale. Over the last few decades, divergent national views have emerged about the interpretations of different clauses of the Indus Water Treaty. The case of the Indus rivers - as they flow across both countries and contributes significantly to their water security - is a test case. The lack of information sharing among the upper and lower Indus basin riparian has constrained the generation of credible and authentic information at the basin scale and thus, impaired the perspective planning on water resources conservation of the basin.

We believe that there are more common interests than aversions between the two countries to ensure the sustainability of water resources in the Indus basin. Both the countries, and more so Pakistan, are facing credible threats to its future water, food, and energy security due to several drivers, related to demography, governance, faulty water resource management, and more recently climate and cryospheric changes. Without any integrated policy on water resources management at the basin scale, there is likelihood of both the countries, particularly

Pakistan, turning into water scarce countries in view of the limited upstream water resources that are not sufficient to meet the unlimited downstream needs for water. Though the integrated basin wide management of the water resources is obligatory for holistic water resources management to address the contemporary and futuristic challenges, keeping in view the current state of relationship between the two countries, it is feasible to think of a step-by-step strategy for addressing the common concerns of the two countries (and Kashmir) on water resources. Such a strategy once in place would ultimately help to build the necessary trust between the two countries and may hopefully, at some point in the future, get catapulted to a basin wide strategy to address all the challenges discussed in the preceding chapters.

4.1 Common concerns in both the countries (and in Kashmir)

Out of all the concerns, explicitly and otherwise expressed by the stakeholders in the two countries discussed vigorously in the preceding chapters, the genuine concerns about climate change and its impacts on the cryosphere and other resources, dwindling limited water resources in the upstream part of the basin, increasing water needs of the growing population downstream, shrinking per capita water availability in both the countries, excessive pumping of groundwater resources, the dwindling groundwater levels, inefficient water usage, cumulative impacts of the cascade of proposed hydropower projects in the upper Indus basin, food security concerns and the increasing frequency of flooding and associated problems, are among the major concerns shared by a wide cross-section of the people in both the countries. All these issues have been deliberated at length in the preceding chapters of the report highlighting their causes and consequences at different spatial and time scales. The two countries could, therefore, agree to develop a time-bound robust strategy and a framework to address these common concerns through a modular basin wide approach that could help to generate the required information and knowledge for guiding the policy for better and sustainable management of the dwindling water resources in the basin. This requires cooperation and collaboration between the two countries so that a mutually agreed upon vision for integrated and joint management of the water resources is implemented in the basin for sustainable development of the waters shared between the two countries.

4.2 Proposed roadmap for addressing the common concerns

The proposed approach for addressing the common concerns can draw upon the good practices already used in various trans-boundary basins across the globe and within the two countries. In this section, we are briefly elaborating on the strategies that need to be undertaken for addressing the common concerns about the sustainability of the Indus Water resources.

a) Climate Change and its impacts the water resources: The indicators of the climate change are quite clear and loud in the Indus basin as has been quantified through a number of studies discussed in the preceding chapters. However, no concerted efforts have been made to assess the impacts of the changing climate in the basin on cryosphere, stream-flows, irrigation, food security or even the drinking water supplies in the long. We need to assess the impacts of changing climate on stream flows and irrigation, food security (particularly down-streams), and drinking water supplies. These impact studies require expertise in the field of climate science, hydrology and modeling and also sharing of the available hydro-meteorological data across the basin. Therefore, these sector-wise futuristic impact studies at the basin scale envisages sharing of the available expertise and information in the two countries to arrive at credible estimates of the impacts of climate change on these resources and sectors. Thus, assessment of the credible impacts of climate change on water resources and related sectors, at appropriate spatial and temporal resolution, are pre-requisite to develop robust strategies for adapting and overcoming the challenges of climate change on these dwindling resources and sectors in the basin.

b) Dwindling water resources in the upstreams: As reported and observed by various researchers, quoted in the preceding chapters of this report, the snow and glacier resources in the upper Indus basin are showing a consistent decline during the last few decades. The declining snow- and glacier-melt, that contributes about 45% to the stream-flow from the upper Indus basin, is one of the major factors responsible for the observed stream-flow decline in the Indus. Therefore, there is an urgent need for a comprehensive scientific study to assess the impacts of the depleting snow and glacier resources on stream-flows and simulating futuristic scenarios of depleting stream-flows so that the policy and decision makers reflect these realistic scenarios in sustainable water resource management strategies. The viability of the ongoing, pipeline and the proposed schemes related to irrigation expansion, energy development, drinking water supplies or industrial use of water is subjected to the sustainable availability of the required waters for these schemes. It is hoped that the up-to-date information and knowledge on the causal factors of the declining stream-flows from these studies, shall inter alia, build and strengthen the trust deficit on this account between the two countries. It is hoped that such knowledge in the public domain shall help to counter the jingoistic noises and

false explanations being doled out about the declining flows observed upstream and downstream of the Indus basin.

c) Shrinking per capita water availability: The two countries have undergone tremendous socio-economic transformation during the last five decades. The changing demographic structure together with the increasing demands of water for irrigation, drinking water and industrial use have reduced the per capita water availability in both the countries. The demographic and development changes witnessed in the two countries, in the recent past, have put tremendous challenges to the sustainability of the depleting water resources in the Indus basin. There is need for adapting multipronged water conservation strategy in both the countries so that the sustainability of the Indus waters is ensured for the posterity. The success stories in the two countries and beyond need to be emulated for developing holistic water conservation strategies across the basin to at least maintain the current per capita water availability for the future generations.

d) Depleting groundwater resources: Due to the exponential increase in the areas under irrigated agriculture, the demands for irrigation water in the two countries have increased correspondingly. The declining surface waters available through the limited canal network for irrigation of the agriculture lands in the two countries is not sufficient to meet the soaring irrigation demands in both the countries. In order to overcome this deficiency, the people have resorted to the pumping of groundwater for meeting the irrigation demands. This pumping of groundwater is widespread, both in the upstream and downstream of the Indus basin, except the mountainous upper Indus basin. The availability of subsidies and cheap power supplies, particularly in the Indian states of Punjab, Haryana and Himachal Pradesh, has further promoted the use of groundwater supplies for the irrigation purposes. As a consequence, the groundwater levels, in both the countries, have drastically depleted putting a question mark on its sustainability.

Declining recharge from the catchment and decreasing streamflows compound the problem. The excessive use of the groundwater for irrigation purposes and declining recharge from the catchment is responsible for widespread land degradation observed in both the countries. Large tracts of the irrigated lands have become unsuitable for agriculture due to alkalinity and salinity. There have been reports of the disproportionate use of the groundwater resources in the two countries due the differential energy and subsidized regimes existing in the two countries and this may impact the groundwater potential downstream as it is intimately linked aquifer system. Over pumping of the aquifers and this differential use of the surface and ground water in the upper and lower parts of the basin could affect the availability of groundwater resources downstream. Therefore, it is very important that the aquifer system shared between the two parts of the Indus is studied in depth for its potential and the interactions so that a groundwater management plan is put in place for the sustainable exploitation of the depleting groundwater resources in the basin.

e) Cumulative impacts of the cascade of proposed hydropower projects: The proposed hydropower development in the Upper Indus Basin (UIB) in India has raised concerns in various sections of the stakeholder particularly in Pakistan. Although seldom analyzed, cumulative impacts occur when several large power projects are built on a single river system resulting in hydrological alterations, an increased and cumulative loss of natural resources, degradation of habitat quality, environmental sustainability and ecosystem integrity. Since, there is no study on the cumulative impacts of the cascading run of the river hydropower projects in the Indus basin, it is necessary to commission such a study so that hydrological and environmental impacts, if any, are highlighted for taking corrective measures. The quantification of the cumulative impacts of the cascade of hydropower projects entails sharing of data on the sitting and design of the proposed projects along with the detailed information on the hydrologic, climatic and environmental setting of the proposed sites. Therefore, the assessment of the cumulative impacts of the proposed hydropower projects in the upper Indus basin entails cooperation and partnership among the relevant institutes and experts in the two countries, so that the research findings on this emerging concern are discussed at the Indus Commission meetings about the smooth functioning of the Indus Water Treaty between the two countries.

f) Inefficient usage of water and food security concerns: There have been several studies, as reported in the literature in the preceding chapters that pointed out the inefficient use of the water for agriculture. Water use efficiency needs to be promoted in both the countries to optimize the use of water for increasing the agriculture productivity to meet the burgeoning food demands of the increasing population. There are valid concerns that the inefficient usage of water for food production, canal seepages, changing climate, increasing population and improving lifestyles in both the countries, may lead to food insecurity in the basin by end of this century. The efficient usage of water for optimizing the food production in the basin needs to be promoted as an important strategy for the judicious use of the depleting water resources in the basin. Similarly, the impacts of the

changing climate on food production needs to be assessed so that the appropriate adaptation strategies are advocated for ensuring that the food production is not adversely affected due to changes in the temperature and precipitation regimes. Better varieties of the agriculture crops need to be developed and promoted so that under the changing climate and declining surface and ground water resources, the agriculture production is optimized through the efficient use of water. The agriculture research, in both the countries, has advanced to a great extent and the two countries need to share and learn from each other's experiences on the efficient use of water and improved agriculture crop yield varieties.

g) Increasing frequency and virulence of floods: The increasing frequency of the flooding is a common cause of concern in both the countries. Both the countries have witnessed some virulent floods recently that resulted in huge damage to the physical infrastructure and humanlife. The flooding phenomenon can be better understood through the quantification of the hydrological and climate processes that operate at the basin scale and beyond. The development of the real time flood forecasting and early warning system at the basin scale envisage scientific and administrative collaboration between the stakeholder in the upper and lower Indus basin encompassing the two countries. This partnership envisages the development of a basin wide hydrological model with real time forecasting and early warning interface with the involvement of the relevant people from both the countries. For developing the forecasting and early warning system for flood disasters in the Indus basin, it is important that the two countries cooperate for their mutual interest, in sharing of the hydrological and meteorological data available through the network of observations set up in the upper and lower Indus basin. In fact, this network of the hydro-meteorological observation network needs to be strengthened and shared through a telemetric mechanism for the optimal utilization of the information for developing flood forecasting and early warning system across the basin.

These common concerns could be categorized into three broad categories:-

I) Sustainability of freshwater resources on a long-term basis

a. Management of catchment to maintain the water yield and runoff quantities

b. Protecting regenerative processes, freshwater eco-systems, water quality

c. Understanding processes affecting river flows, like

- climate change
- development impacts
- floods, etc

II) Efficient water use in the basin

a. Improving efficiency at the water use level: drivers, bottlenecks and best practices

b. Competitive use of water

c. Water harvesting in marginal water access areas (rainwater, wastewater, etc)

d. Livelihood concerns, water rights and other factors influencing water distribution.

Both the countries can benefit from each other's experience in many areas through case studies

III) Water governance

a. Information, openness, knowledge-base

b. Constructive dialogue on water issues including implementation of IWT, convergence towards common interpretations

From the perusal of the common concerns and the suggested mechanisms for addressing these concerns, as elucidated above, it is clear that there is a dire need for collaborative efforts to develop a joint initiative to address these issues in the entire Indus basin. The initiative is aimed at generating a large body of knowledge on the Indus water system and the associated physical environment for guiding decision about the sustainable development and conservation of water resources shared between the two countries. Protection of river water resources, equitable water sharing, sharing of information and consultation among the upper and lower riparian should be amongst the guiding principles for developing institutional collaboration in case of Indus water. Such an initiative, when put in place, will result in exponential benefits across the board in the two countries including the possibilities of institutional information and expertise sharing, consultation between upper and lower riparian stakeholders, sharing of best management practices in water and related sectors and this may, inter alia lead to confidence building and political stability in the region.

4.3 Involvement of academia, government and non-governmental actors to address "common concerns"

The major seven common concerns and the mechanisms for addressing these concerns under the joint initiative, as

elucidated above, envisages a close cooperation and partnership among various stakeholders in the two countries that have an interest in promoting peace in the region or are working on various aspects of water resources management, peace and reconciliation, environmental conservation, climate change impact and adaptation studies at academic, government and non-government level. There is a need to identify the relevant institutes and experts primarily from the two countries and also from other countries that have interest in the subject and are willing to working under a consortium to accomplish various component studies for addressing the common concerns about the sustainability of Indus water system. The following potential organizations and interest groups may be roped into the consortium for taking up this challenging task of joint studies for understanding and addressing the common concerns on Indus water in the two countries:-

a) Academia:

i) University of Kashmir, Srinagar, India

ii) Jawaharlal Nehru University, New Delhi, India

iii) Indian Institute of Technology, Roorkee, India

iv) University of Engineering and Technology, Lahore, Pakistan

v) Peshawar university, Peshawar, Pakistan

vi) Quaid-E-Awam University of Engineering, Science & Technology (QUEST), Nowabshah, Pakistan

vii) National University of Science and Technology (NUST) Islamabad

viii) Department of Geography, Gottingen University, Gottingen, Germany

ix) Centre for South Asian Studies, Freiburg, Germany

x) School of Civil Engineering and Geosciences, Newcastle University, Newcastle, UK

b) Governmental agencies:

i) National Geophysical Research Institute (NGRI), Hyderabad, India

ii) National Institute of Hydrology (NIH), Roorkee, India

iii) Central Water Commission (CWC), Govt. of India, New Delhi, India

iv) Water and Power Development Authority (WAPDA), Pakistan

v) Pakistan Council for Research in Water Resources (PCRWR), Pakistan

vi) Global Change Impact Studies Centre. Pakistan

c) Non-governmental agencies:

i) Centre for Dialogue and Reconciliation, New Delhi India

ii) Jinnah Institute, Pakistan

iii) Sustainable Development Policy Institute (SDPI), Pakistan.

iv) Observer Research Foundation (ORF), India

v) Friedrich-Naumann-Stiftungfür die Freiheit (FNST), Germany

vi) Atlantic Council, Washington, USA

vii) International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

viii) International Water Management Institute (IWMI), Colombo, Sri Lanka

ix) World Bank, Washington

x) Asian Development Bank (ADB), Manila, Philippines

The exact roles and responsibilities of each of these organizations in the consortium shall be decided based on their interests and expertise on the subject. It would be appropriate to convene a workshop on the theme of the joint Studies inviting participations from all these academic, governmental and non-governmental agencies identified above. In fact, participants from other relevant institutes that have expertise and interest in the subject shall also be invited to make it an inclusive academic interaction and exchange. The proposed workshop shall help to fine-tune the various modules of the proposed mega joint initiative for developing a robust strategy and action plan to address the common concerns of the two countries about the Indus water system.

4.4 Informed diplomacy to deal with policy issues

The setting up of the consortium with constitution from various academic, government and non-governmental organizations of the two countries, would itself be tantamount to a major step towards finding amicable solutions to the common and emerging concerns on the sharing of the depleting Indus waters between the two countries. The proposed joint initiative envisages the exchange and sharing of information and expertise, close coordination, and frequent interactions between the various stakeholders from the two countries. The joint and collaborative proposed research on water issues has a potential for generating the required goodwill and trust for addressing other festering bilateral issues between the two countries. The generation of information and knowledge on

the seven common water concerns under the collaborative and joint ownership will help the two governments to deal effectively and appropriately with the policy issues governing the sharing of waters between the two countries. It is hoped that, the repository of knowledge to be jointly generated by the Consortium under the initiative shall provide the informed confidence to the policy and decision makers of the two countries to approve the action plans for addressing these common concerns, even if, it may require supplementing the existing Indus Water Treaty (IWT). We strongly believe that the putting in place and strengthening of the consortium should be first priority under the initiative and would hopefully lead to the joint Indus basin management of the water resources between the two countries in the foreseeable future.

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